Fascinating Experiments in CHEMISTRY

by François Cherrier

WITHDRAWN

Technical Consultant: Maurice Finot, Professor of Chemistry and Physics

STERLING PUBLISHING CO., INC. NEW YORK
Oak Tree Press Co., Ltd. London & Sydney

La MARQUE PUBLIC LIBRARY
1011 BAYOU RD
La MARQUE, TEXAS

Galveston County Library System
Galveston County, Texas

351308

OTHER BOOKS OF INTEREST

Fascinating Experiments in Physics

American Chameleon
Anatomy for Children
Angelfish: Its Life Cycle
Bee Is Born
Bird Is Born
Butterfly Is Born
Butter Side Up!
Frog Is Born
Lobster: Its Life Cycle
Mosquito Is Born
Turtle Is Born

Translated by E. W. Egan

Adapted by Dennis Schuchman

Photographs and layout by the author

Second Printing 1979

Copyright © 1978 by Sterling Publishing Co., Inc.
Two Park Avenue, New York, N.Y. 10016
Original edition of this book was published in France under the title "Expériences de Chimie Amusante" © 1974 by Librarie Hachette, Paris.
Distributed in Australia by Oak Tree Press Co., Ltd.,
P.O. Box J34, Brickfield Hill, Sydney 2000, N.S.W.
Distributed in the United Kingdom
by Ward Lock Ltd., 116 Baker Street, London W.1
Manufactured in the United States of America
All rights reserved
Library of Congress Catalog Card No.: 78-57788
Sterling ISBN 0-8069-3102-7 Trade Oak Tree 7061-2595-9
3103-5 Library

Contents

Equipment *9*
Supplies and some tips *15*
Crystals and precious stones *17*
From the invisible to the visible *45*
Small fireworks *57*
Magic colors *75*
Six experiments and unusual applications *83*
Chemistry, atoms, and the world we live in *93*
Index *96*

A word about these experiments

Did you know that you can set off a small volcanic eruption using bicarbonate of soda, white vinegar, a bit of paint and liquid detergent? That onion juice and salted water are invisible inks? That cigarette ash can be used to set a sugar cube on fire?

Such feats are all possible through chemistry, a science that is constantly changing our lives. Synthetic fabrics, building materials, plastics . . . . one discovery after another. Our possessions, our houses, our clothing, all come from laboratories!

It will be very simple for you. You will assemble the essential equipment yourself and you will use safe, readily available substances. Many of them will be found in your medicine chest or among your family's household supplies. As for chemicals with unfamiliar names—magnesium sulphate, chrome alum, calcium chloride, potassium ferricyanide—these are not dangerous nor hard to obtain.

Safety precautions are extremely important, especially when the experiment involves heat. Proper protection for your eyes is essential. Your teacher will tell you which experiments you can do on your own, and which should be done under supervision.

Complete and precise instructions and numerous illustrations will draw you into the world of experimentation. Strange sights will unfold before your eyes and you will see all sorts of changes take place that illustrate the beauty of scientific and natural phenomena and make these fascinating experiments a game that will never cease to amaze you.

You will become a scientist of a sort.

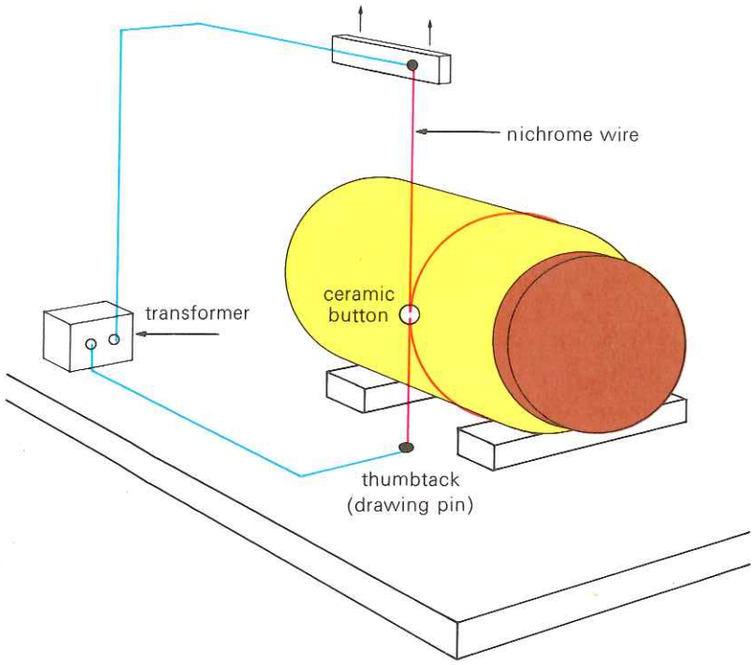
Equipment

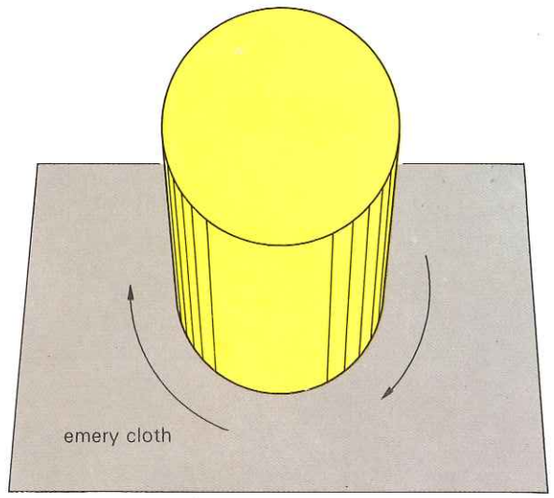
Benjamin Franklin said that a good workman must know how to file with a saw and saw with a file. In other words, you must not be a slave to tools and equipment. On the contrary, you should learn to get along without them, to overcome difficulties by discovering uses and functions for things that are suited to your purposes even if they were not designed to be used that way. Many scientists have been able to deal with problems in the same way and some great discoveries have been made with the aid of equipment that can be found anywhere. The photograph below shows the sources of the laboratory glassware that you see on the opposite page. At the far left are various glass jars and containers with lids, in the middle are former light bulbs and on the right are jars that have been cut down by a very simple method explained on page 10. We shall see also, on page 11, that all the other instruments that you will need can be made easily from readily available materials.
All the experiments described and explained in this book have been achieved with the following equipment:

Glassware: mustard and jam jars; bottles of different sizes and shapes; small, wide-mouthed containers; jars with air-tight lids for holding preserves, pickles or jam (these vessels can be seen on the opposite page at the far left, with their lids painted black); a large Pyrex® glass with a capacity of half a litre; a shallow Pyrex® container; glass tubes for holding pills or spices. Round bottom flasks, cupels (assaying cups), vessels, and a crystallizer (seen in the middle and on the right of the picture on the opposite page), while not indispensable, are quite useful and require only a little patience to make them.

How to make round bottom flasks, cupels, crystallizers and measuring glasses.

Materials: used light bulbs of different sizes; ordinary jars and bottles; 12-volt nickel-chrome (nichrome) or nickel-silver electrician's wire (electrical resistance wire); a 12-volt model railroad transformer or battery; a ceramic button; a small saw; opaque adhesive tape; sheets of emery cloth (medium and fine).





Cut the bottles, jars or bulbs at the desired height, as shown in Drawing 1. Make a small saw mark at the spot on the vessel where you are going to cut. Then loop the wire around the bottle at that point. Pass the ends of the wire through the holes of the ceramic button and connect them to the two wires of the transformer. Keep everything in the right position by pulling gently with one hand on the upper small wood block that holds one of the branches of nichrome wire while the other hand keeps the jar firmly on the two blocks of wood. The lower branch is held with a thumbtack (drawing pin) stuck in a board serving as a base. A switch with a pedal or a push-button (like a doorbell) operated by the foot and mounted on one of the wires that come from the transformer, can complete this circuit. A few seconds of heating are enough to cleave the glass along the line of the wire.

After this is done, the sharp edge of the vessel can be smoothed off with well-dampened emery cloth. Use medium-grain first, then fine, as shown in Drawing 2. Don't overlook any sharp edges. If you don't have emery cloth, use a whetting stone (for sharpening knives). To stand round bottom flasks, place them on corks (see page 8).

To make a measuring glass, use a small bottle or a narrow cylindrical jar having a uniform diameter throughout its height. Cut out the neck and sand the edge (see above). Attach a strip of adhesive tape lengthwise to the jar. With the aid of a kitchen measuring cup or some other vessel whose volume you know exactly, pour in a quantity of water sufficient to fill the glass. Then trace on the tape a mark at the top and indicate next to it the number of millilitres (cm^3) of water that you have poured in. Next, mark subdivisions on the tape. In this way you can divide a jar holding 100 cm^3 of water into 20 equal parts, each representing 5 cm^3.

Instruments and accessories

A small enamelled saucepan, a tablespoon (all retired from use), lids from tin canisters, upper part of a plastic bottle for use as a funnel (2), filter paper (for making coffee, for example), plastic spatula (for stirring), old bowl (mortar) and a stone (pestle).

Small accessories to make

Wire support for funnel (3), a small ring joined to a larger one; wire grill stand (4), see page 12; wire tripod.

How to make an alcohol lamp

An ink bottle filled with alcohol is fitted with a cork with a hole in the middle (make a small hole with an awl and enlarge it with a rat-tailed file). Slide a small metal tube into this hole, about equal in diameter to a pencil, containing a wick (from a hardware dealer). The tube must extend 12 mm above the cork. After use, cover the lamp with a small bottle that can replace the cork.

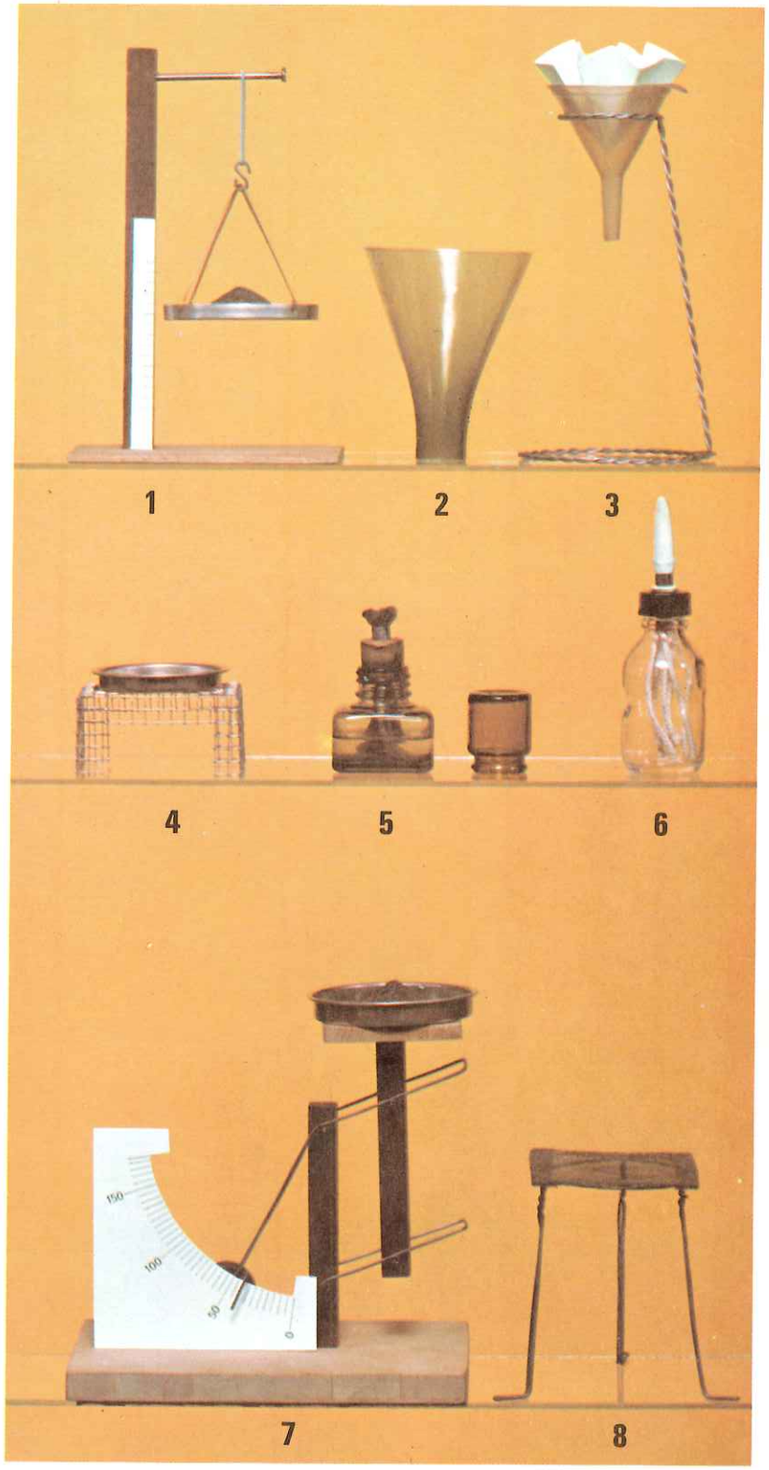
Variation (6): Take a bottle with a medicine dropper, cut the rubber part, replace the glass tube with a metal tube and put the wick through it and cover it with a small cap.

How to make scales

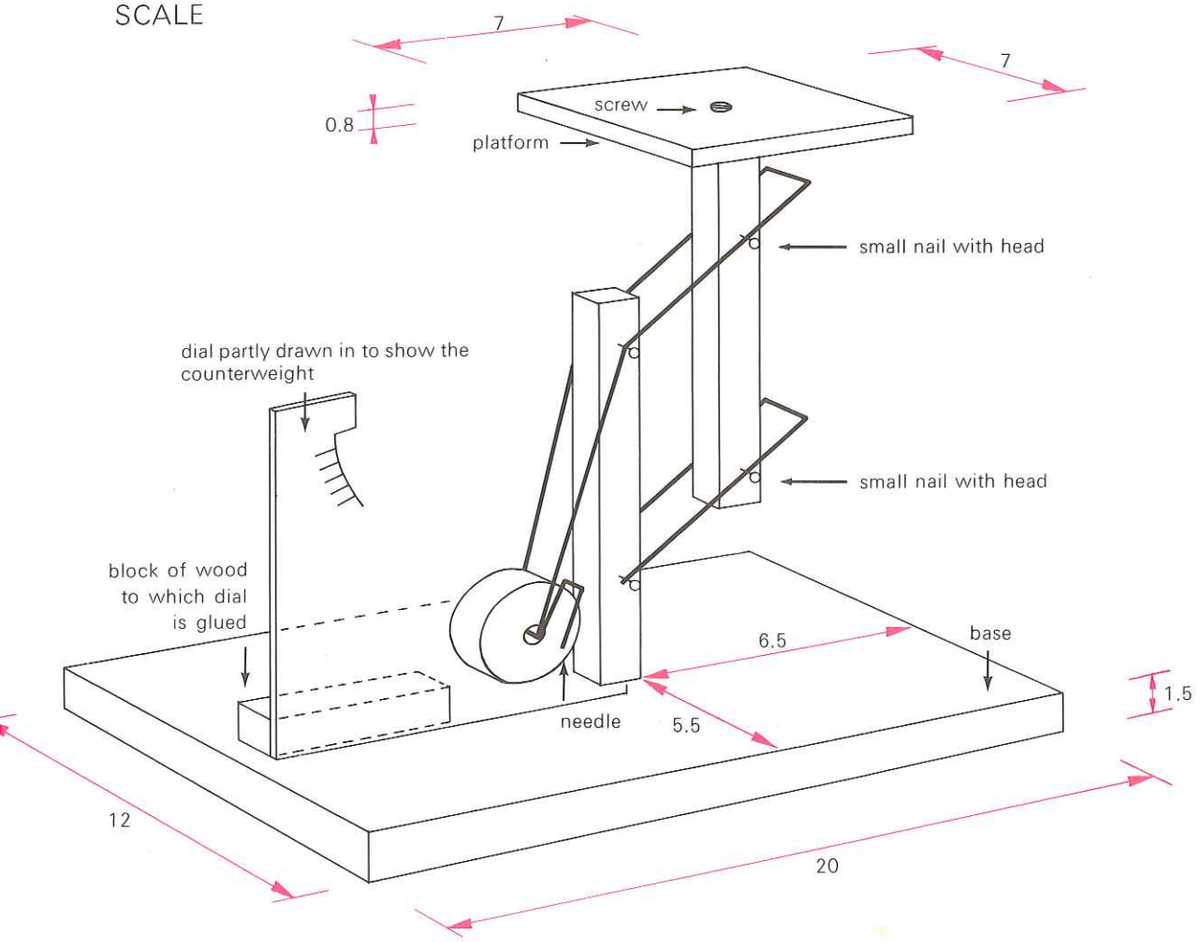
The simplest version (1) consists of a tin canister lid with four evenly spaced holes in the rim. Two pieces of copper wire are inserted in the holes so that they cross one another. A hook connects the tray to an elastic band which in turn is suspended from a large nail stuck in the stand. To calibrate your scales, place weights or any other objects of known weight on the tray and check them against the indications on the side of the stand.

This scale (7) is a more precise instrument. All the details of its construction are in the drawings on pages 12 and 13.

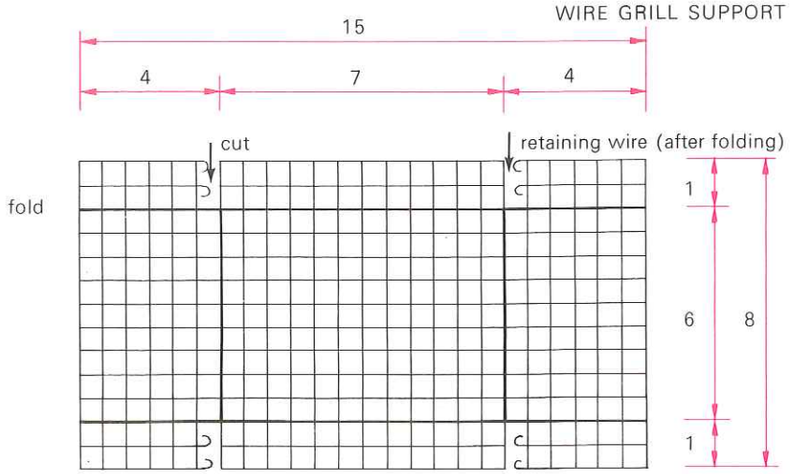
To calibrate this scale, adjust the angle of the upper arm so that the needle rests on zero. The counterweight must be several millimetres from the first amount on the dial. Place the lid that holds the substance to be weighed on the tray. Then place some weights on the tray and note the weight on the face of the scale.
If the needle is not on zero when empty, place a little wedge to the left or right under the base to adjust it.

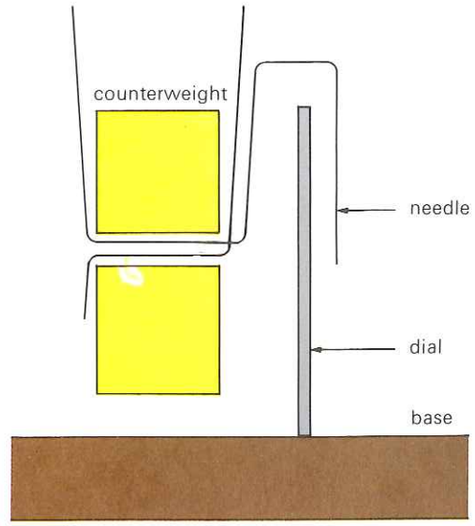


SCALE



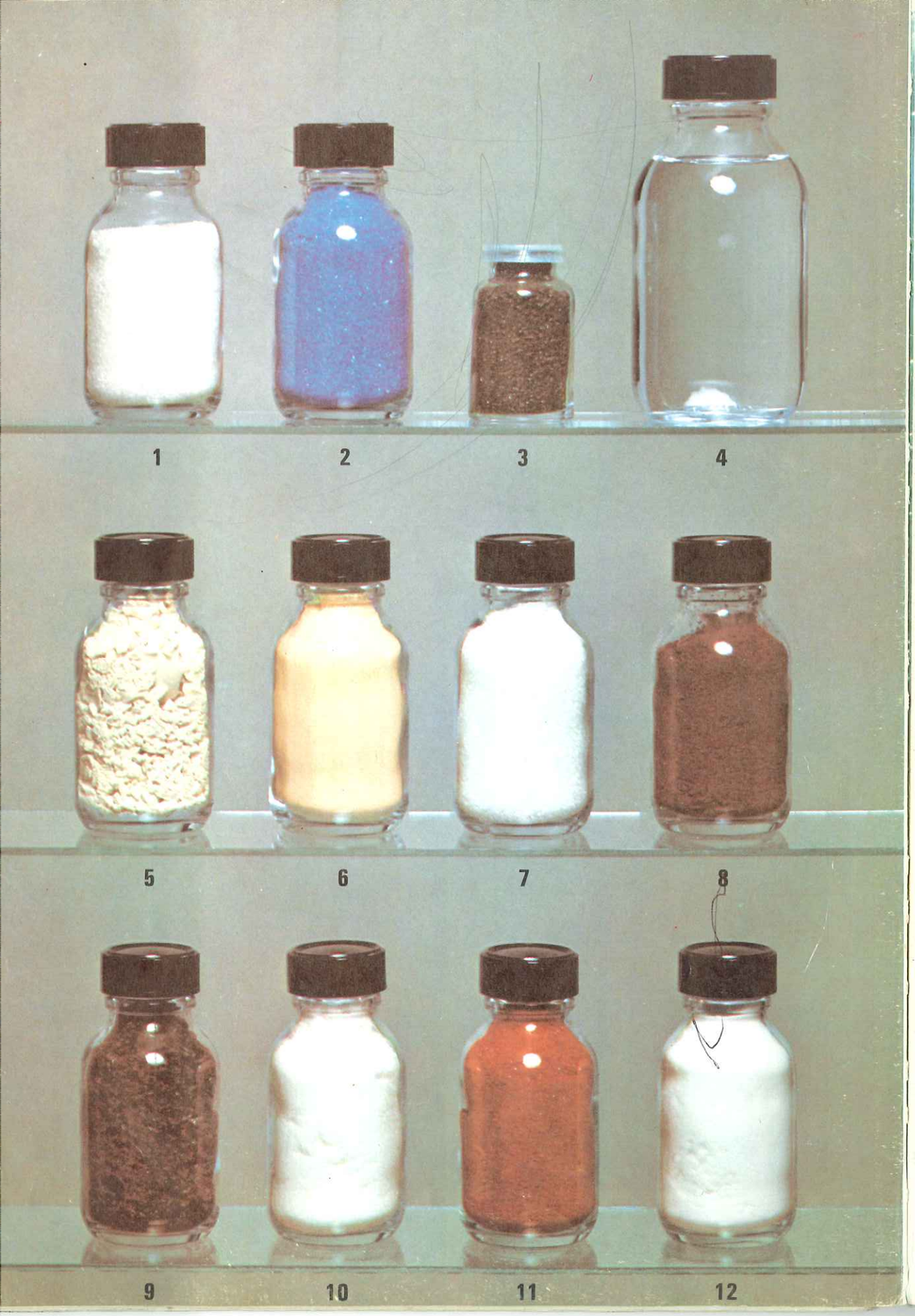
WIRE GRILL SUPPORT





pass the wire through the counterweight to form the needle of the scale

BALANCE ARMS



Supplies

Principal chemicals

1. *Magnesium sulphate* (Epsom salts): pharmacist, housewares shop. 2. *Copper sulphate:* garden supply shop, pharmacist. 3. *Ferric citrate:* pharmacist. 4. *Sodium silicate* (or pebble liquor): pharmacist, housewares shop. 5. *Calcium chloride* (as a dessicant): housewares shop, pharmacist. 6. *Sulphur* (flowers of sulphur): garden shop, pharmacist, housewares shop. 7. *Potasssium alum* (ordinary alum): pharmacist, photo supply shop. 8. *Cobalt chloride:* pharmacist, laboratory supply dealer. 9. *Chrome alum:* photo supply shop, pharmacist, laboratory supply dealer. 10. *Benzoic acid* (frost on vanilla): pharmacy, laboratory supply dealer. 11. *Potassium ferricyanide:* photo supply, pharmacist, laboratory supply dealer. 12. *Potassium nitrate* (powder): pharmacist, laboratory supply dealer.

Two products less often used:

Aluminum sulphate: pharmacist.
Potassium permanganate (powder or crystals): pharmacist, photo supply shop.

Materials that can be found at home:

Household ammonia (5%), bicarbonate of soda, iodized alcohol, white vinegar, naphthalene balls, powdered sugar, starch, oxygenated water (10 volumes), red cabbage, glycerine, kitchen salt.

Articles that can be obtained from a mechanic or plumber:

Iron powder or filings, zinc powder.

Articles that can be obtained from housewares shops and groceries:

Charcoal, varnish (lacquer base or gum arabic base), distilled water.

Some tips

☐ Chemical products come in three grades: analysis, par and technical. The least expensive is the technical (sold in garden and housewares shops). The most expensive, analysis, comes from the pharmacy. All three can be used in the experiments in this book.

☐ All pharmacists, especially those who do analyses, have or can obtain in a few days the products in the first category above. By grouping your purchases and ordering quantities of 100 grams or more, laboratory suppliers can meet your needs.

☐ The products used in this book do not appear on any list of dangerous products whose sale is controlled by law—none of them are hazardous when used carefully. Nonetheless, you should take precautions, whether household products, chemicals or pharmaceuticals are involved: *do not leave anything within reach of very small children, wash your hands after experiments, and so on.*

☐ As a general rule, do not improvise any risky experiments. Stick to the ones described in this book. Don't try to change them or add any chemicals not mentioned in the book. For success, all you need is to carefully follow the explanations in this book, which are precisely illustrated by photographs.

☐ Scientists, researchers and chemists do not always succeed in their experiments on the first try. Therefore, be patient and be doubly painstaking if by chance this happens to you.

☐ If the chemicals are sold to you in paper envelopes or in temporary wrappings, put them in flasks or jars with air-tight caps that have been cleaned thoroughly and carefully labelled.

☐ In experiments involving heat and explosions, be sure that you have suitable eye protection, such as goggles.

☐ When you use potassium permanganate, use a spatula to avoid staining your hands. Or, remove stains with a cotton wad soaked in oxygenated water or sodium bisulphite.

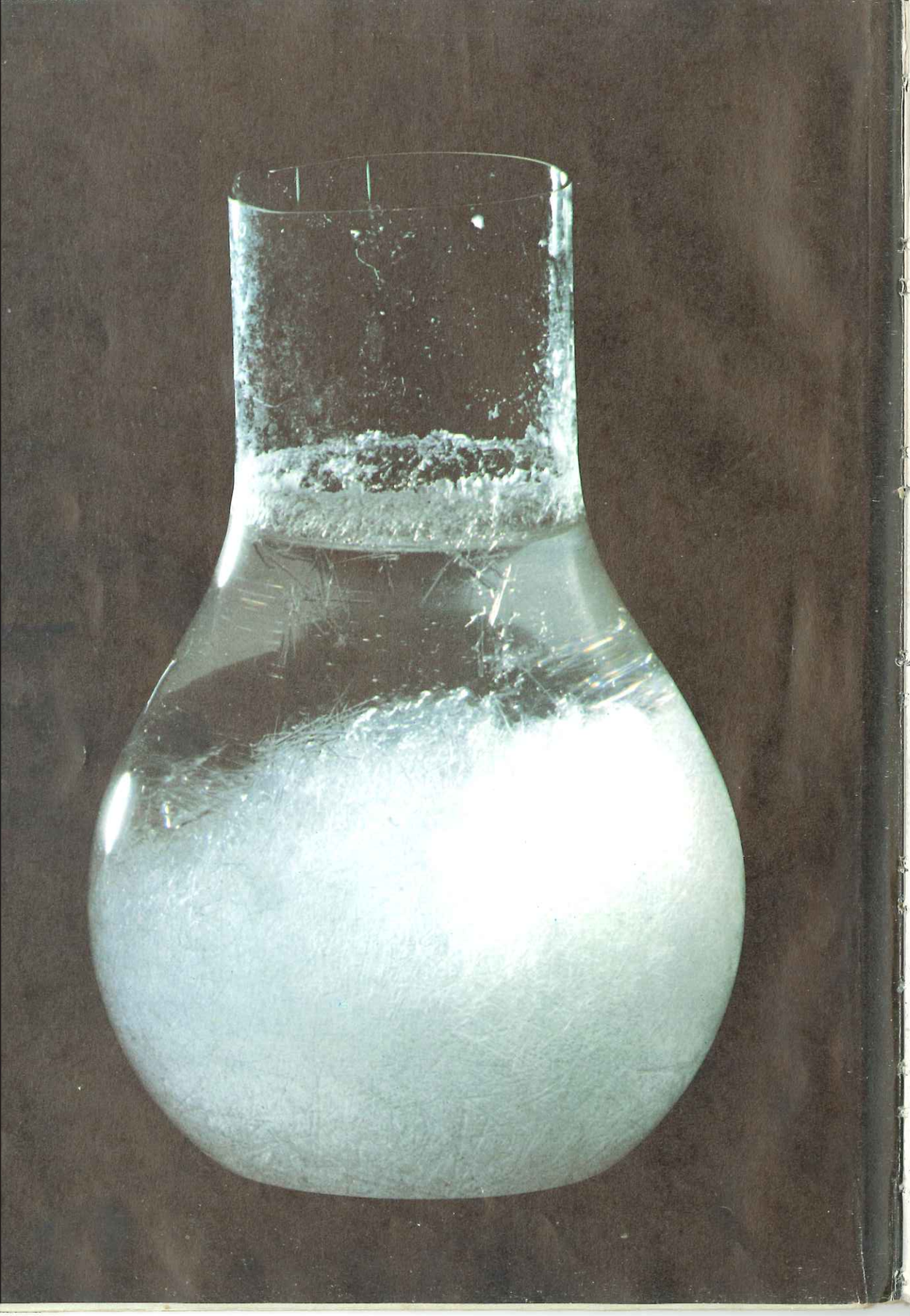
☐ Sparks (see chapter on fireworks) are no more dangerous than the flame of a match or candle. Simply avoid putting your head or your hands too close.

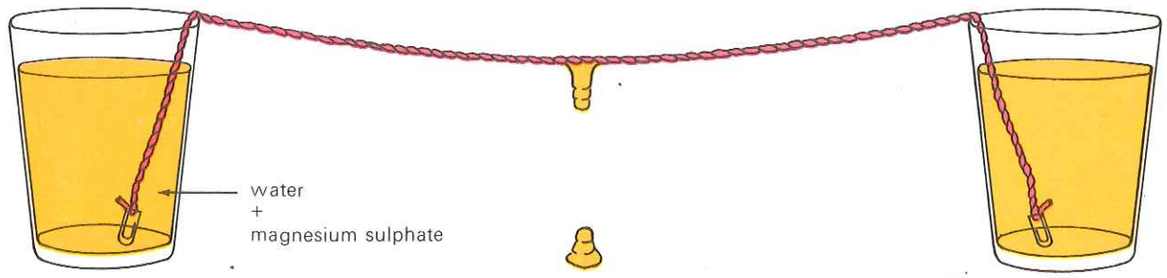
☐ If you are especially interested in one of the subjects of this book or if you have a question, don't hesitate to consult scholarly or popular works. Ask your teachers for advice.

We hope that the wonders which you will both see and create will teach you that conducting chemical experiments can bring you much more than scientific knowledge alone. Many poets have already preceded you along this route.

19 Liquid . . . or solid?
19 Stalactites and stalagmites in miniature
20 Arborescent crystallization on a glass plate
20 Projecting crystals on film
23 Giant crystals
24 Precious stones
26 The diamond merchant's chest
27 Chunk of synthetic mineral
29 One crystal inside another
30 From sphere to octahedron
31 Sugar crystals
32 Christmas decorations
33 Costume jewelry
35 Coral crystals
39 The underwater forest
43 Frost in summer

crystals and precious stones





Liquid . . . or solid?

Supplies: Magnesium sulphate; enamelled saucepan; round bottom flask or ordinary glass.

Heat 2/3 of the water from a round bottom flask in the saucepan. Remove from the heat and dissolve in it the same amount of magnesium sulphate. Immediately pour this mixture into the flask and do not touch it again.

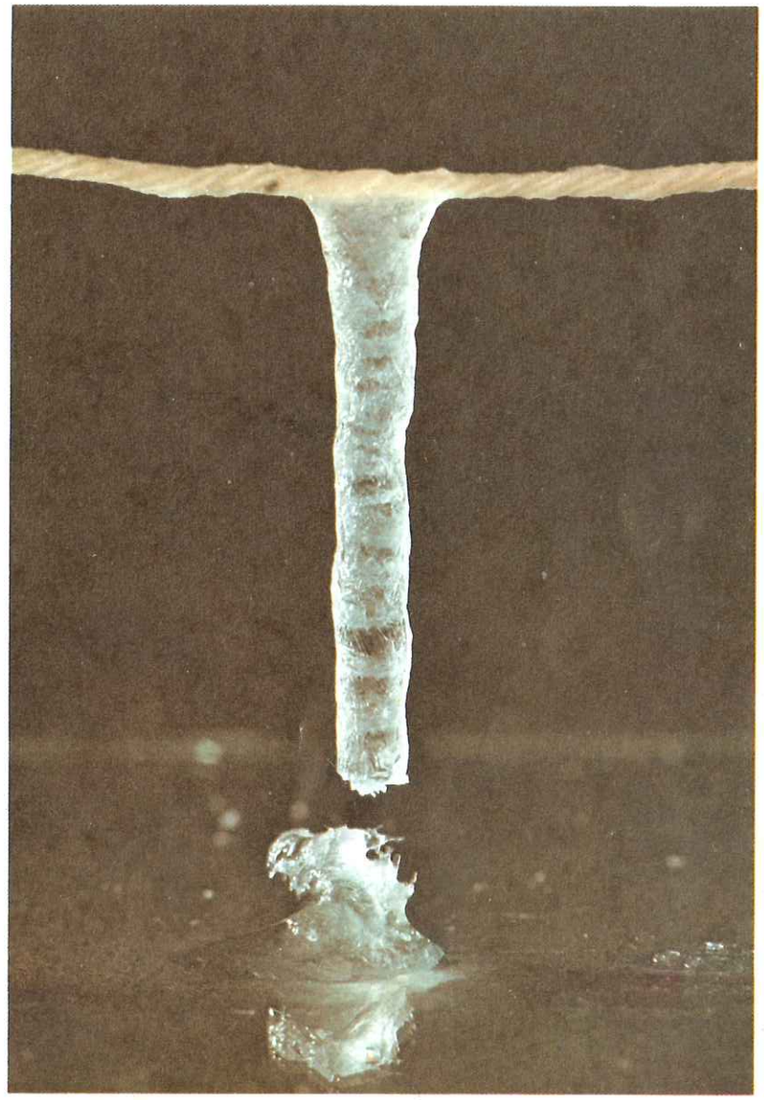
□ As it cools, small crystals will form and grow for several hours until all the liquid is solidified. In case this doesn't happen, gently add a small lump of magnesium sulphate to the liquid to induce complete solidification.

Stalactites and stalagmites in miniature

Supplies: Magnesium sulphate; two glasses; a length of cotton yarn; enamelled saucepan; two paper clips.

Heat the water (one glass) in the saucepan. Dissolve 2/3 of a glass of magnesium sulphate in the hot water. Pour equal amounts of the solution thus obtained in each of the two glasses. Attach a paper clip to each end of the yarn and put one end in each glass (see drawing above).

□ After several moments a drop of liquid will form in the middle of the yarn and fall. It will solidify in the air (that is, crystallize). You will then see a stalactite form (photo at right) and below it, a stalagmite. This process is similar to the one that has produced limestone columns in some natural caverns—but much faster!



Arborescent crystallization on a glass plate

(photo at right)

Supplies: glass sheet 30 x 30 cm; liquid detergent; copper sulphate.

Put 1/3 teaspoon of detergent in a glass of water and pour the mixture over the glass plate. Tilt the plate to the left and right to spread the solution and then allow it to dry. Now dissolve 5 grams of copper sulphate in 10 cm^3 of hot water. Pour this solution evenly over the glass plate, tilting the glass as needed. Then put the glass flat, exposed to the air in front of a window and watch what happens.

□ The spreading of the solution is helped by the detergent. The water in this thin layer evaporates and the copper sulphate crystallizes rapidly in a unique arborescent (treelike) pattern.

Variation: The same thing can be done with a saturated solution of potassium ferricyanide in water.

Projecting crystals on film

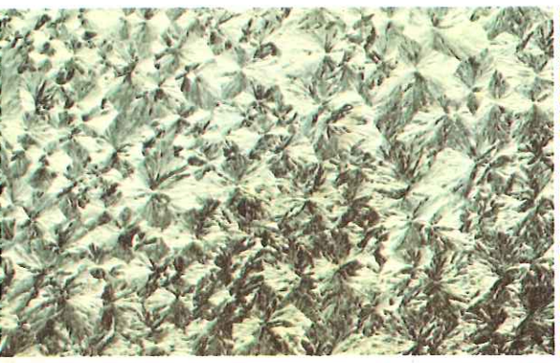
(photos this page)

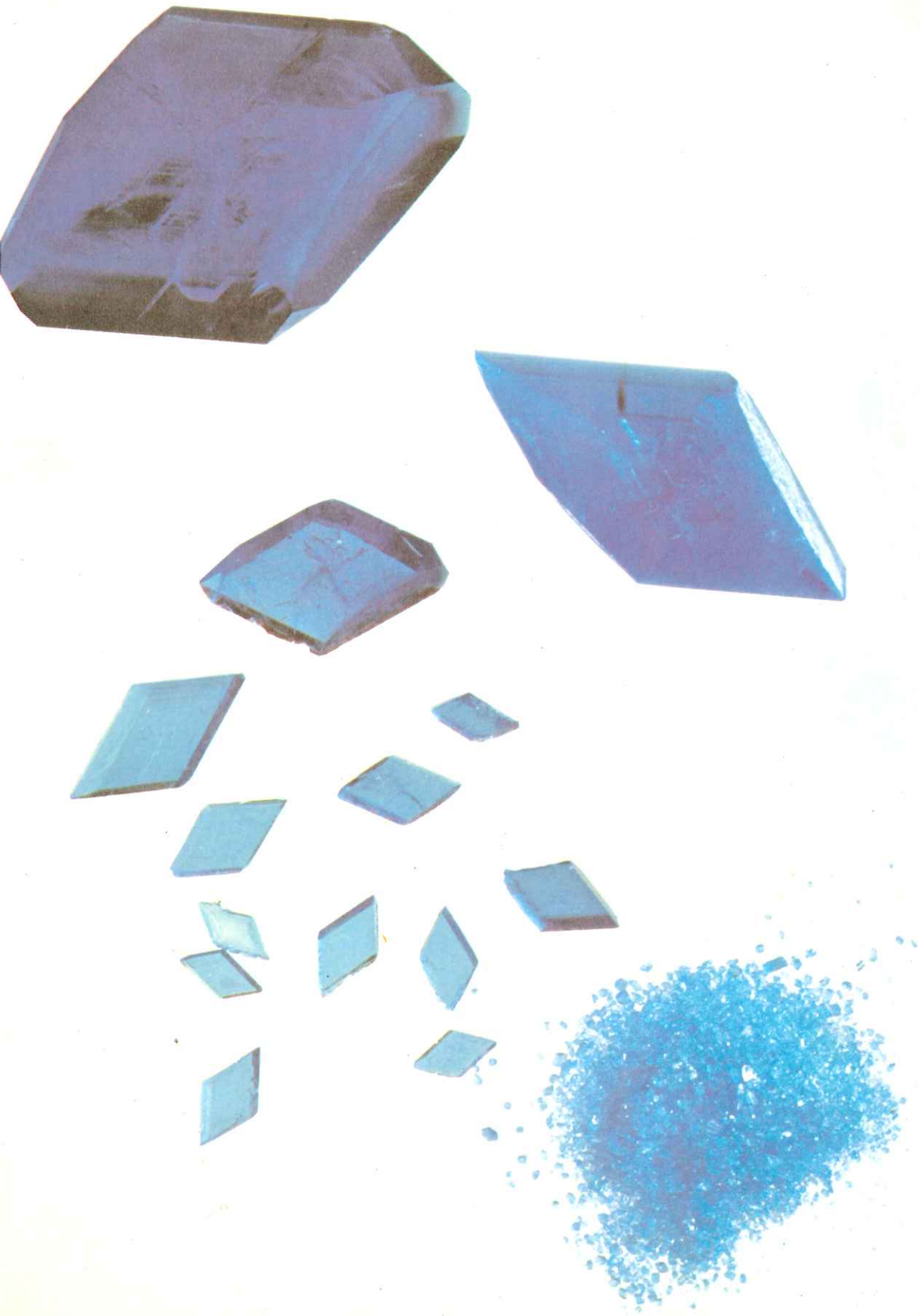
Supplies: scraps of black-and-white film (developed but not exposed); potassium ferricyanide; slide mount for a 35 mm transparency (see photo above).

Begin by dissolving the ferricyanide to the saturation point in water. Mark the emulsion side of a scrap of film—it is the side that adheres slightly to a damp finger. Pour a bit of the solution on this surface and let the excess run off. Do not touch the surface. Place it in air in front of a window and watch.

□ The water evaporates and in the thin layer of emulsion, magnificent crystals grow and spread before your eyes. When the show is over, place the film in the slide mount and project it in order to see all the details.

Variation: Dissolve 1/4 of an aspirin tablet in several drops of ether and pour over Cellophane® (photo below left).





Giant crystals

Supplies: copper sulphate; crystallizer or glass dish; a small rod; fishing line; enamelled saucepan; filter paper; a glass.

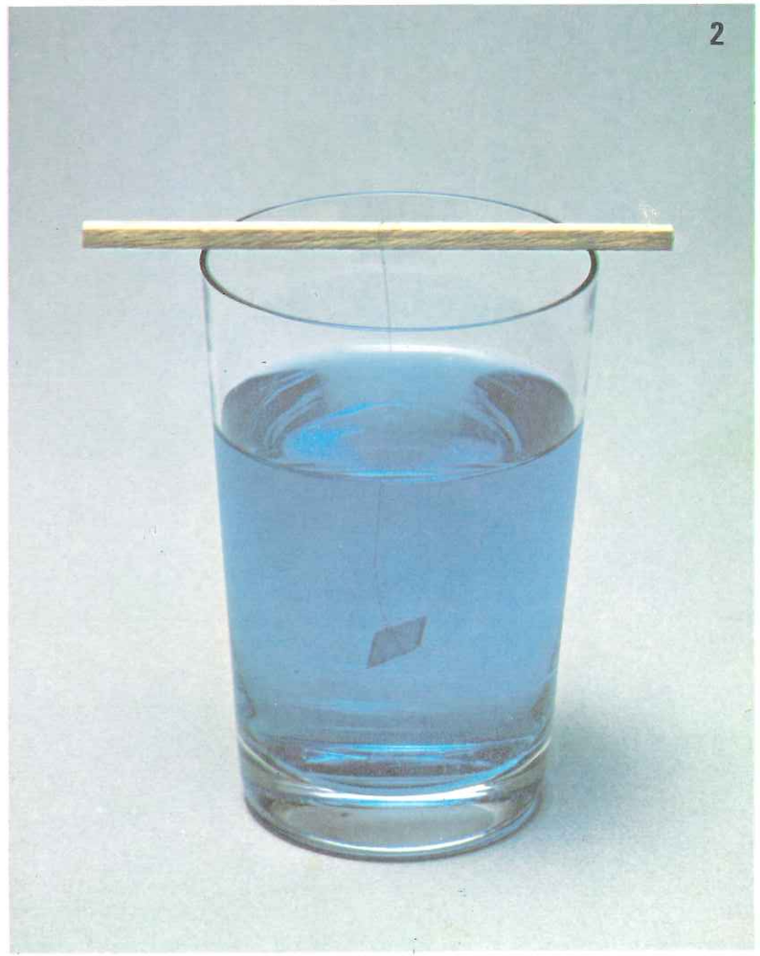
Completely dissolve 50 grams of copper sulphate in 100 cm³ of very hot water in the saucepan. If the solution contains impurities, filter it.

Pour the solution into the crystallizer and place this on a very firm support free from all vibration. Do not touch the crystallizer. After two hours, small crystals will cover the bottom of the dish (Photo 1). Pick out a fairly large one and tie it to the fishing line (which should be very clean) so that it is suspended in the middle of a glass (Photo 2). Then make a new solution with 150 cm³ of water and 75 grams of copper sulphate, as previously. Pour into the glass, which should also be very clean.

Place the glass on the immobile support, and when the solution has cooled a bit (after 15 minutes), put a rod with the small crystal suspended from it in place. In one day, the small crystal will have eaten all its "food" and grown quite large.

Now, in another glass, pour a new solution prepared as before, and when it has cooled a bit, put your crystal carefully in it. Continue in this way, using larger and larger vessels as your crystal grows and increasing the volume of the solution. (Maybe you will have the patience of those Russian scientists who, a few years ago, showed the public a crystal weighing 2500 kilograms!)

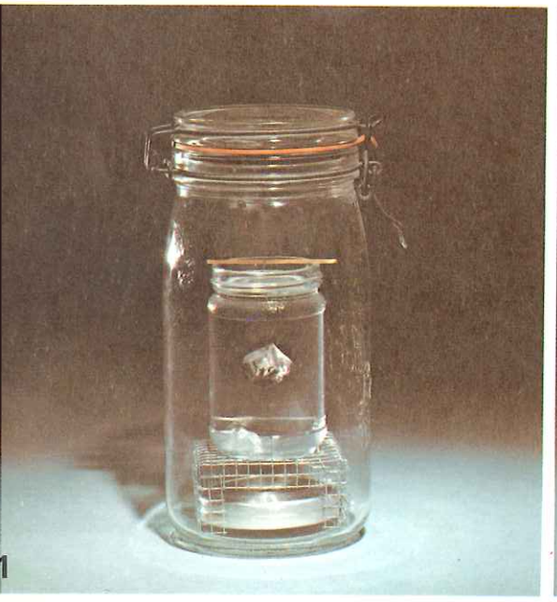
□ The hot water lets you dissolve more copper sulphate (the solute) than cold water could. When the solution cools, it has more solute in it than it can hold at that temperature. It is said to be supersaturated. To re-establish equilibrium, this excess will separate from the rest, assuming its natural crystalline form. The small crystal serves as a nucleus and thus grows as the excess solute is deposited on it.



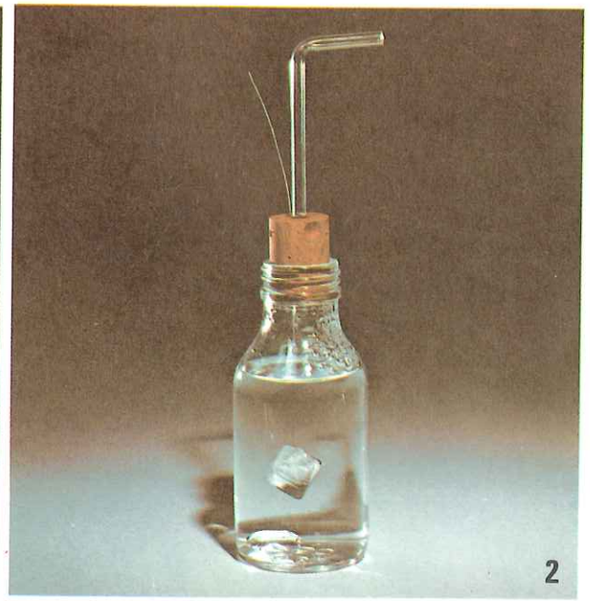
Precious stones

Supplies: chrome alum; potassium alum; magnesium sulphate; crystallizer; glass plate; wide-mouthed jar (250 to 300 cm³) with a cork stopper with a hole; glass tube (medicine dropper); enamelled saucepan; fishing line (see page 11).

To obtain a transparent octahedron (eight-sided solid) (top of opposite page), begin by completely dissolving 15 grams of potassium alum in 100 cm³ of very hot water. Pour this solution into the crystallizer and cover with a glass plate. Then place on a firm and motionless support (see page 23) and do not touch. Two or three hours later, remove a fine



1



2

crystal, fairly large and regular in shape, and attach it to a length of fishing line.

Prepare a new solution with 200 cm³ of water and 30 grams of alum. Filter it and then pour it into the jar on a firm support. When the solution is almost completely cool, put the cork on the jar. The fishing line holding the crystal is wedged by the tube passing through the cork (see Photo 2). The small crystal will then grow very slowly and almost flawlessly for about three days. To make it grow still more, simply replace the solution with a fresh one (see page 23).

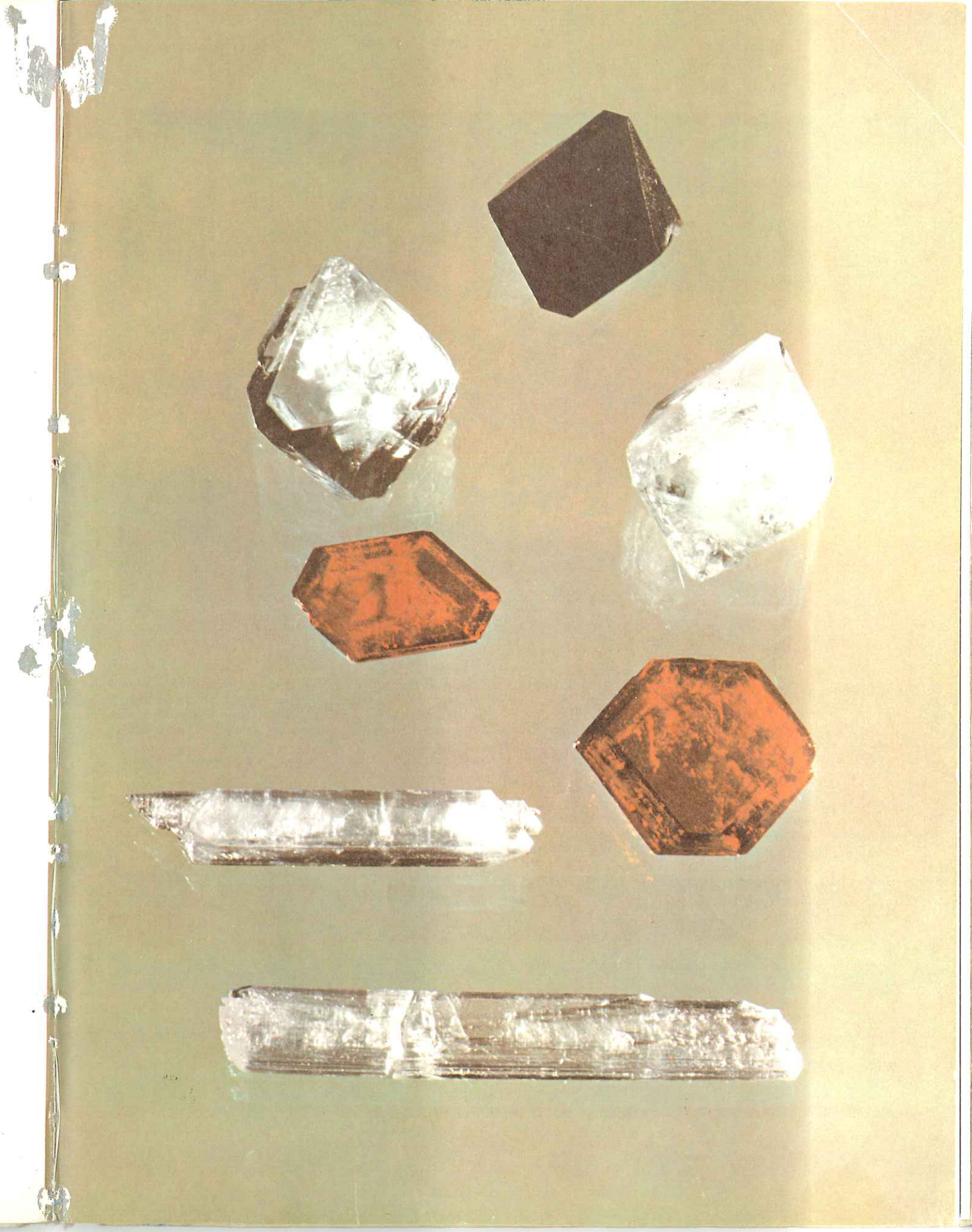
Another process for obtaining a well formed crystal is shown in Photo 1. In the bottom of preserve jar place a container of dessicator (a drying agent used to protect cameras from humidity), or pieces of calcium chloride. Over this put a wire support (see page 12). Place on this a small open jar containing the solution. Attach the crystal nucleus to a rod and place the latter across the rim of the jar. Then put the lid firmly on the large jar. You have constructed a dryer. To make other "precious stones," proceed in the same way, but with the following proportions: octahedron (purplish-black, top of photo)—40 grams of chrome alum to 100 cm³ of water; red crystals—45 grams of potassium ferricyanide to 100 cm³ of water (select a fairly large nucleus); long crystals (bottom of photo)—dissolve magnesium sulphate in hot water to the saturation point (in one night it can reach 8 or 9 cm in length).

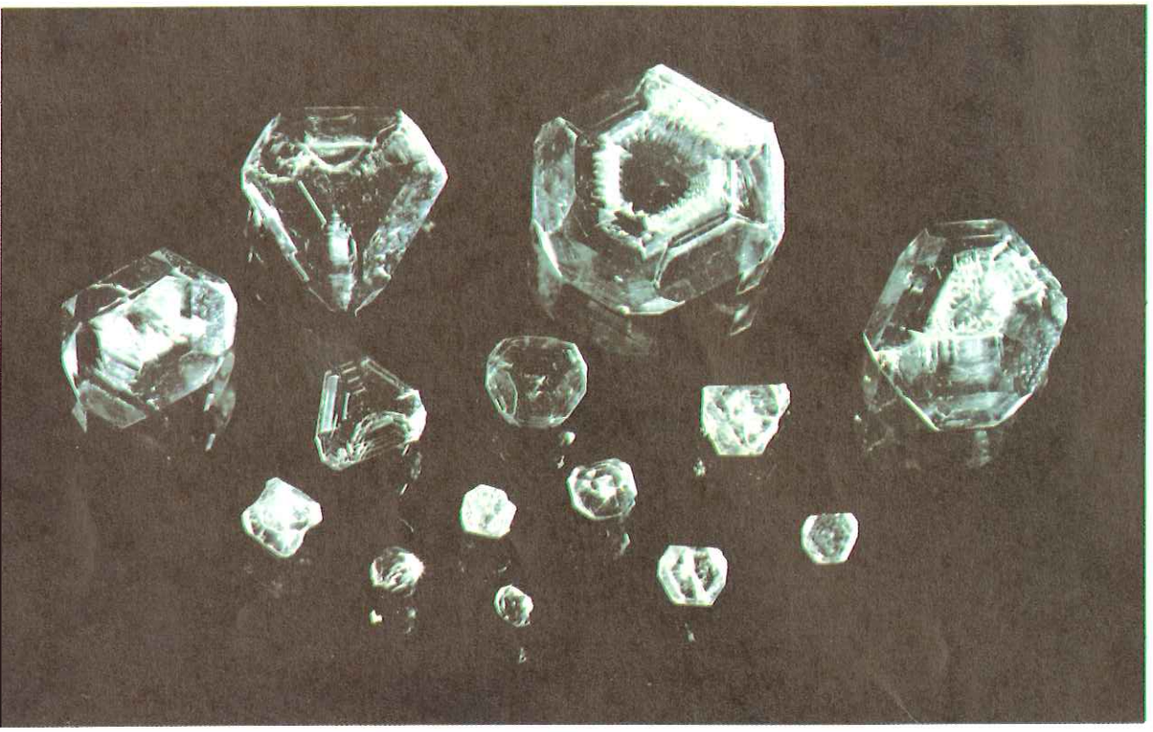
If by accident your solution precipitates (forms thousands of tiny crystals), start over again; heat it in the saucepan to dissolve the solids again.

If the nucleus disappears after being placed in the solution (the liquid is still too hot, or there is not enough solid matter, or the nucleus is too small), pour it off carefully and start another nucleus.

In most cases, the slower the growth of the crystals, the better their form. You can do this by slowing down evaporation (Photo 2) or by letting the water of the solution be absorbed by the dessicator (Photo 1).

□ These substances are much more soluble in hot water than in cold. When the hot solution cools, it has more solute than it can hold—it is supersaturated. The evaporation of water from the solution also causes supersaturation—it will have dissolved the maximum that it can hold.





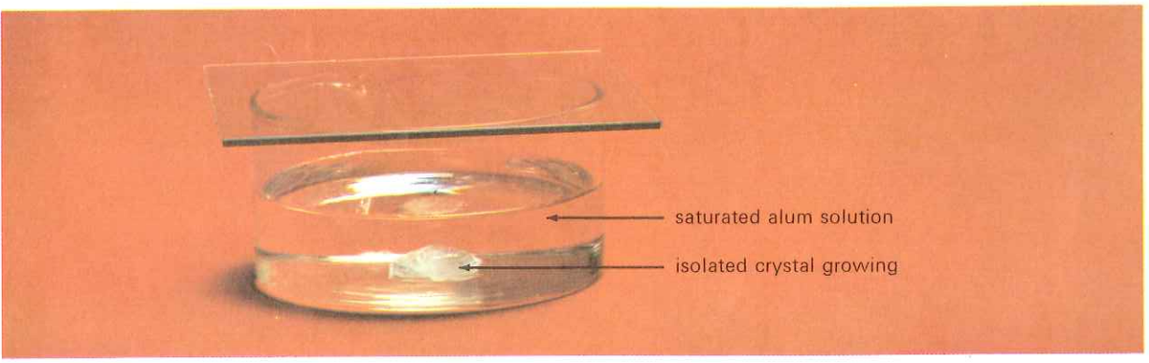
The diamond merchant's chest

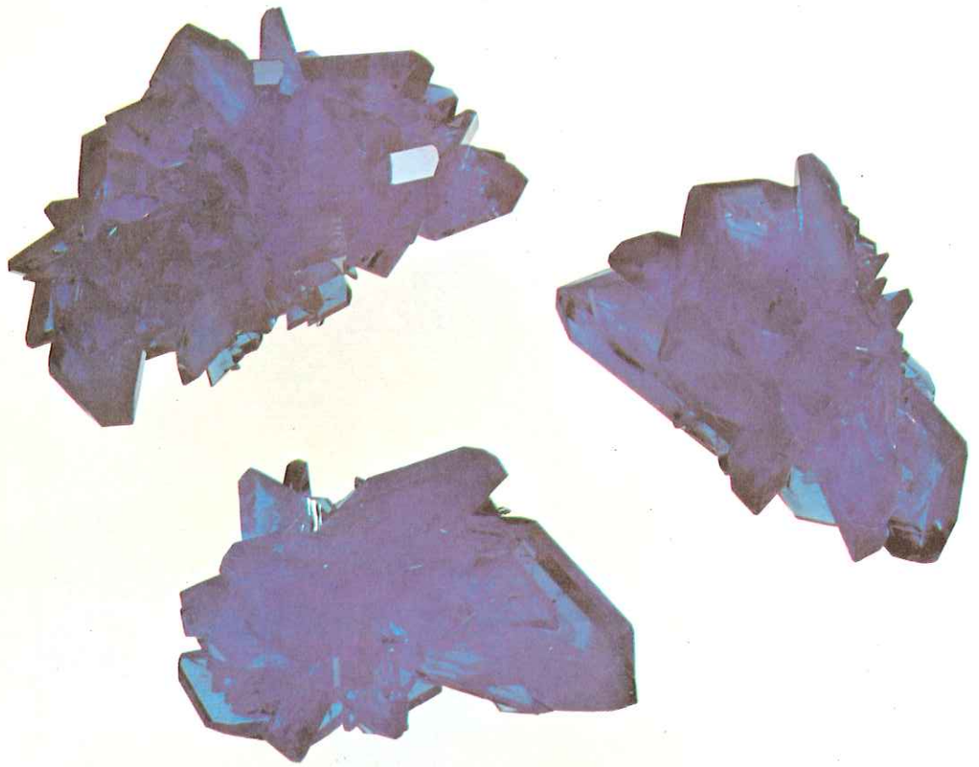
Supplies: potassium alum; crystallizer or deep dish; glass plate, filter paper.

Heat 100 cm^3 of water in a saucepan until it starts to quiver. Then take it from the flame and completely dissolve 15 grams of potassium alum in it. Pour this solution into the crystallizer on a very steady support. Let it cool a bit and carefully cover it with a glass plate. About two hours later, small crystals will be deposited. Pick out a well formed one and make another identical solution. Filter it, pour it into a very clean crystallizer and let it cool a bit before carefully placing the crystal you have selected into it. Cover with the glass plate. (This should be very clean, too. See photo below.)

□ The form of this alum crystal is different from the one obtained by suspending a nucleus in the middle of a solution (see page 24), for when placed on the bottom, it cannot grow equally on all sides. However, even if the shape is modified, the angles are not: this is common to all crystals of this type.

Do not touch it for a day or two. You can then remove the crystal and put in a fresh solution. Repeat this operation several times and the crystal will become very large. Several crystals placed in a jewel box will give off thousands of marvellous sparkles.





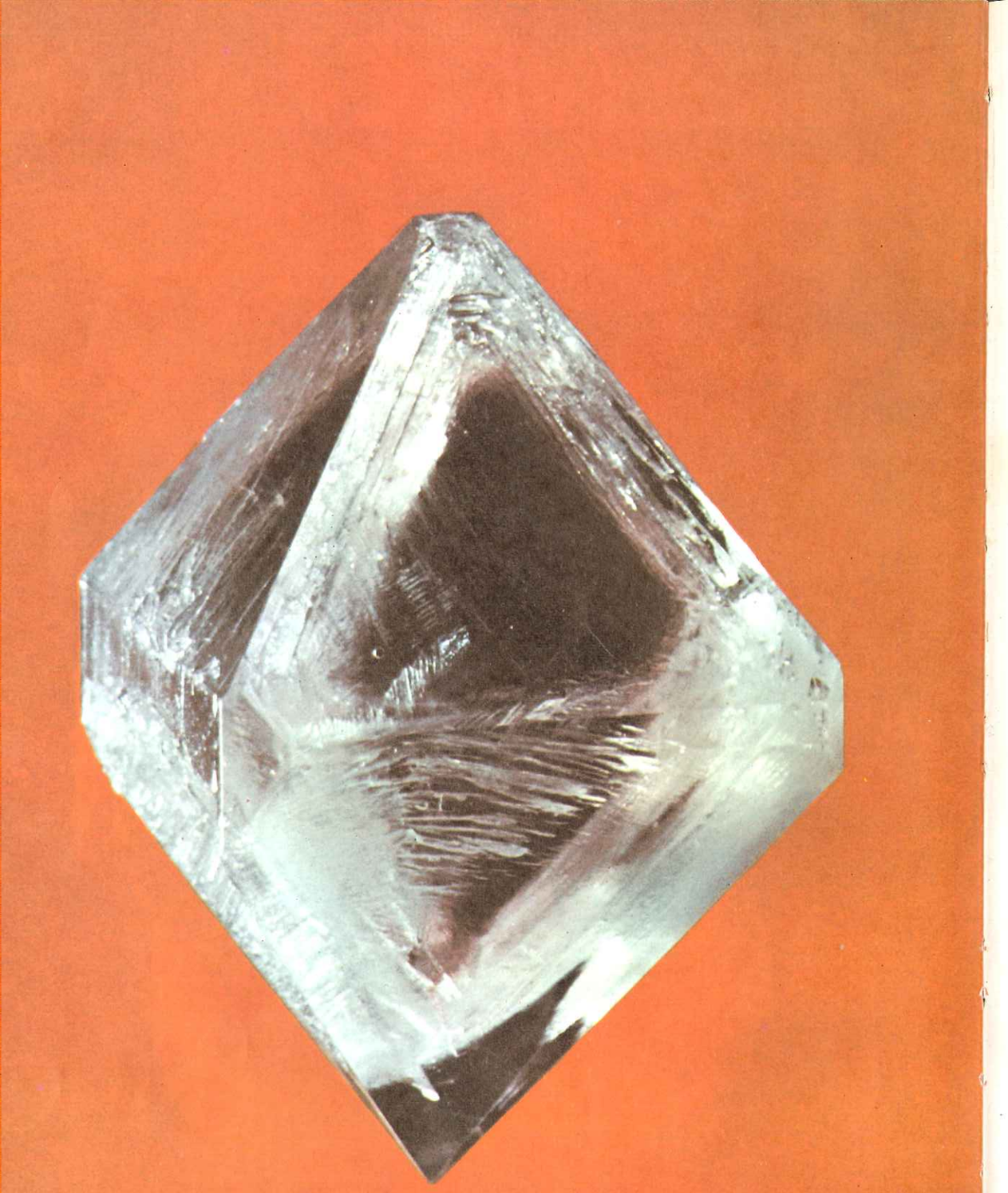
Chunk of synthetic mineral

Supplies: copper sulphate; jam jar about 9 or 10 cm in diameter; enamelled saucepan.

Completely dissolve 100 grams of copper sulphate in 200 cm^3 of very hot water. Pour this solution into the jam jar and place it on a very firm surface. Do not touch it for two days. Then pick out one or two well-formed chunks that have appeared and put them aside. Reheat the solution containing the remaining crystals in the enamelled saucepan, adding a small quantity of copper sulphate (about equal to half the volume of the crystals that you set aside). When everything is well dissolved, let the solution cool for a few moments, and pour it over the chunks, which you have placed in the bottom of a jam jar. Two days later you will have beautiful chunks of crystal similar to the ones in the photo above.

Variation: In the first solution put a piece of limestone on the bottom of the jar; the crystals will adhere to this and the combination will look even more like natural crystals.

□ The minerals that make up rocks are nearly always in the crystalline state, but we rarely see them in the form of crystals. These are "mineral flowers," spontaneous works of nature, and they are the objects of splendid collections in museums or in specialized shops. You have just done what nature has often done in giving birth to them—in cracks and cavities in rocks—concentrations of matter dissolved by water heated by volcanic eruptions have formed solutions. In the course of the gradual cooling that ensued, crystals have grown and developed freely.



One crystal inside another

Supplies: potassium alum; chrome alum; crystallizer or deep glass dish; glass plate; two similar wide-mouthed bottles (capacity of 250 cm³), one of which has a cork with a small glass tube passing through it; enamelled saucepan; fishing line.

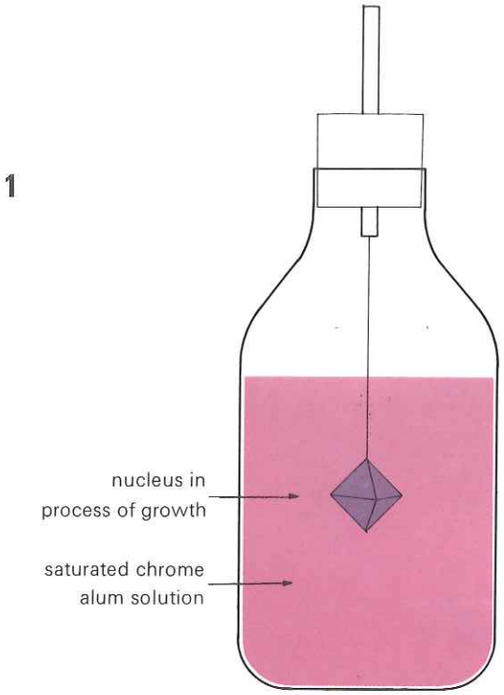
Completely dissolve 40 grams of chrome alum in 100 ml of very hot water in the enamelled saucepan. Pour this solution into the crystallizer on a motion-free support (see page 23) and cover it with a glass plate. Leave it alone for two or three hours, then remove a good crystal from it, fairly large and regular in form and attach this to a length of fishing line. Make a new solution of 200 cm³ of water and 80 grams of chrome alum. Filter it, then pour it into a bottle placed on a motion-free support. When the solution is almost completely cool, put the cork on the bottle. The string holding the crystal is held firmly by the glass tube (Drawing 1). Let the crystal grow for three days. Then make a solution of potassium alum, 30 grams dissolved in 200 cm³ of hot water.

Filter the solution and pour it into a second bottle identical to the first. When it is almost completely cool, uncork the first bottle and move the cork and crystal (don't touch the crystal) to the second bottle (Drawing 2). Leave it alone for two or three days. The crystal will continue to grow as though it were in the original solution, but this time it will be transparent.

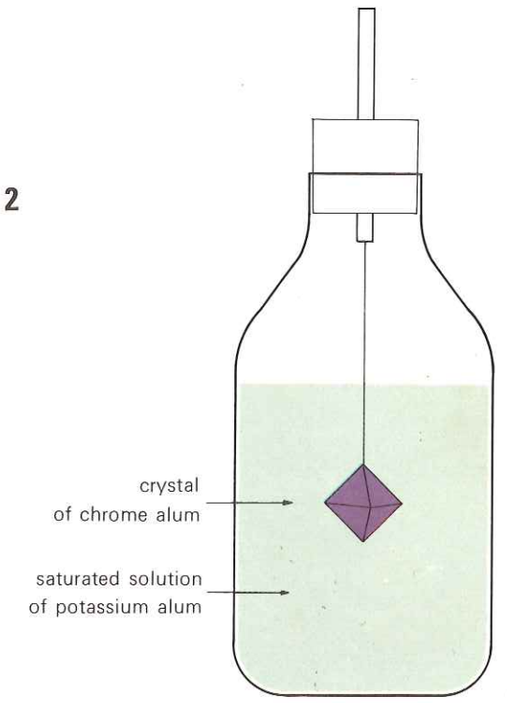
Variation: Proceed in the same way with nickel sulphate (solution 1) and magnesium sulphate (solution 2), dissolved to the saturation point in hot water. The crystal will be green in the middle and transparent on the outside.

□ These pairs of substances crystallize in the same way and can replace one another in any proportion in the same crystal: they are *isomorphs*.

1



2

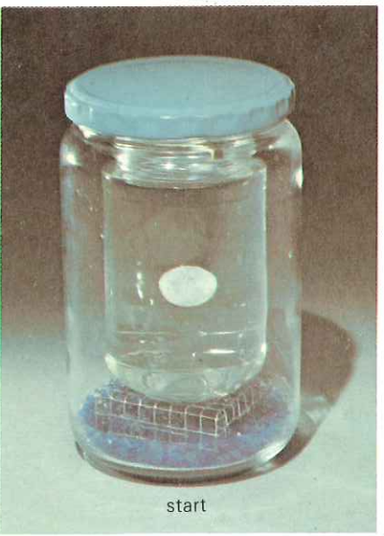


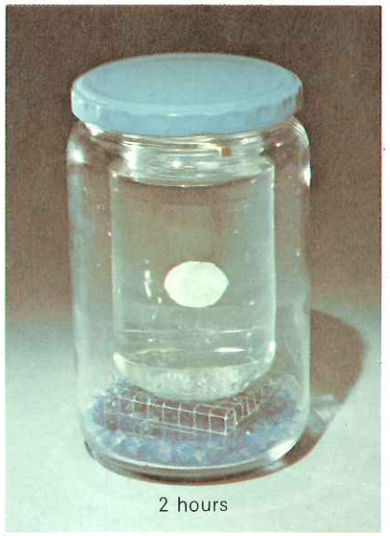
From sphere to octahedron

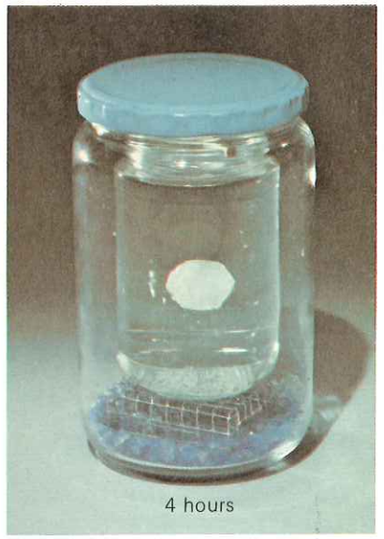
Supplies: a large crystal of potassium alum (see page 24) in the form of a marble; fishing line; small rod; large jar with air-tight cover; small jar without lid that will fit into the large jar; calcium chloride or silica gel; wire mesh support (see page 12); potassiun alum.

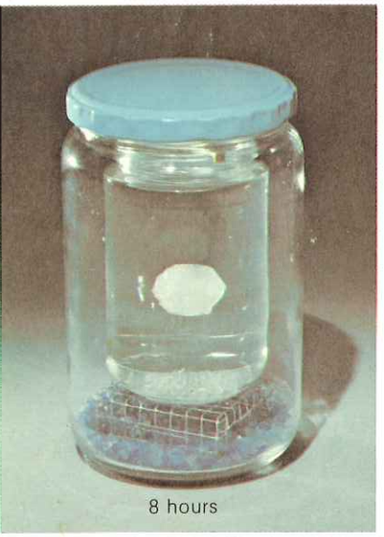
Hang the rounded crystal from the rod with fishing line so that the "marble" can be suspended in the middle of the small jar. Place several pieces of calcium chloride in the bottom of the large jar, then put in the wire mesh support. Make a solution of 30 grams of potassium alum in 200 cm^3 of very hot water. Filter it and pour it into the small jar. Place the small jar on the wire support. The whole arrangement is then placed on a very firm surface. A little while later, when the liquid is almost cool, put the round crystal in and cover the big jar tightly.

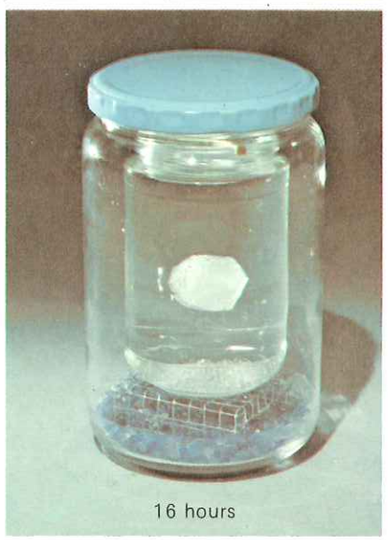
□ The crystalline form of potassium alum is an octahedron. Even when we use a rounded-off nucleus, the alum will, as it grows, try to resume its original shape. This is what the experiment shows us, as seen in the photos below, taken during its course. In this case we have replaced the calcium chloride with a mixture of silica gel and cobalt chloride in order to bring about the slow absorption of water by the mineral, which changes color.

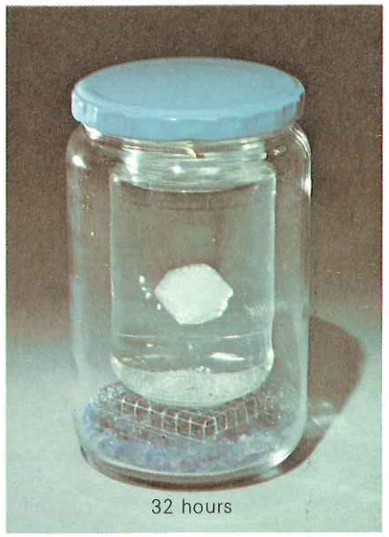

start

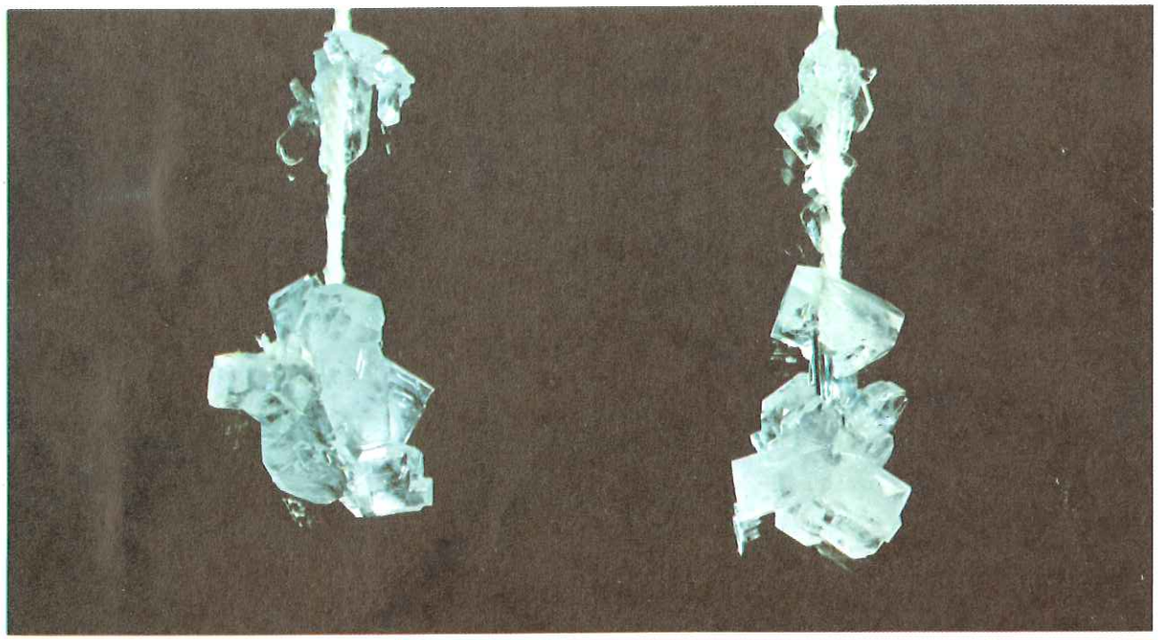

2 hours


4 hours


8 hours


16 hours


32 hours



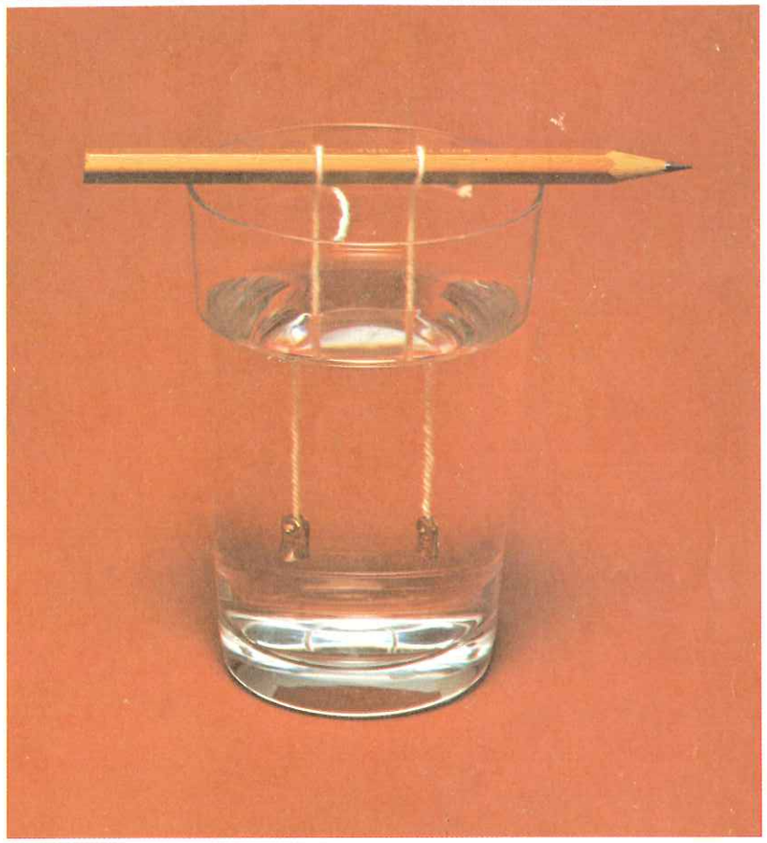
Sugar crystals

Supplies: powdered sugar; large glass; saucepan; pencil; cotton yarn; paper clips.

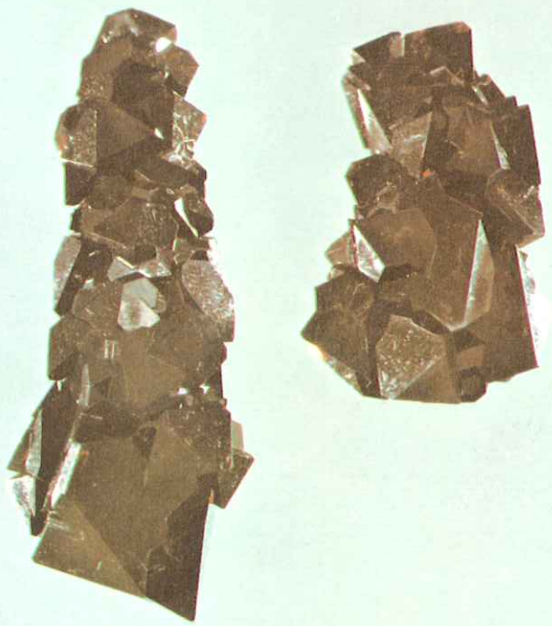
Pour 2/3 of a glass of water into the saucepan. Heat until the water begins to quiver, then dissolve as much sugar as possible, stirring well (for 50 cm^3 of water, about 200 grams of sugar). Do not overheat. Then pour the liquid back into the glass. Fasten two or three strands of yarn to the pencil. Weigh the strands down by attaching paper clips to the ends, as in the picture at the right. Place the pencil over the rim of the glass and put the whole apparatus in a quiet spot on a firm support.

Several days later you will see that little crystals are attached to the yarn. They will grow and develop in the next few days and you will have beautiful crystals like the ones in the photo above.

□ Crystallization of sugar is brought about by the evaporation of water. This process is very slow because the solution is very thick.



1



Christmas decorations

Supplies: potassium alum; tall, narrow jar of about 300 cm³ capacity; cotton yarn; nuts or washers; enamelled saucepan.

Completely dissolve 50 grams of potassium alum in 250 cm³ of very hot water in the saucepan. Pour the solution into the jar. Attach two strands of yarn as long as the jar to a pencil. Weigh them down with nuts and dip the whole thing in the jar, placing the pencil across the rim of the jar. Place the jar on a firm support and leave it alone for a whole day. You can then remove some astonishing "candles" (photo at right).

□ The cotton serves as a wick on which the excess solids in the solution can form thousands of tiny crystals which will sparkle brilliantly on your Christmas tree.

2

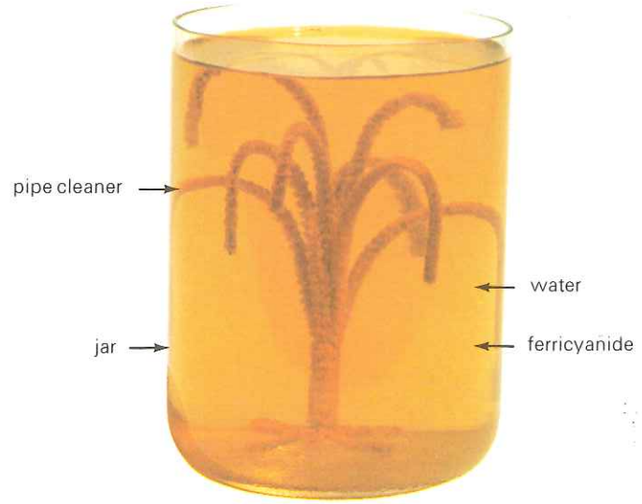
Costume jewelry

Supplies: chrome alum; potassium ferricyanide; crystallizer or deep glass dish; glass plate; wide-mouthed jar, capacity 250 to 300 cm³, with a cork through which a small glass tube is passed; enamelled saucepan; fishing line.

Completely dissolve 100 grams of chrome alum in 200 cm³ of very hot water in the saucepan. Pour the solution into the jar and attach a small piece of chrome alum to a piece of fishing line. The line is held by the glass tube that passes through the cork. Immerse the crystal in the solution and put the cork in place on the jar. In a day or two you will have jewels like the ones in Photo 1. The line from which they were hung will enable you to attach them to a cord.

The pendant (Photo 2) is made in the same way with potassium ferricyanide (50 grams to 100 cm³ of water).

□ The excess solids in the solution are too much to form a single crystal. When a nucleus is introduced into these solutions, already supersaturated, you will see the formation by "contagion" of other nuclei near it, which join one another and grow together.

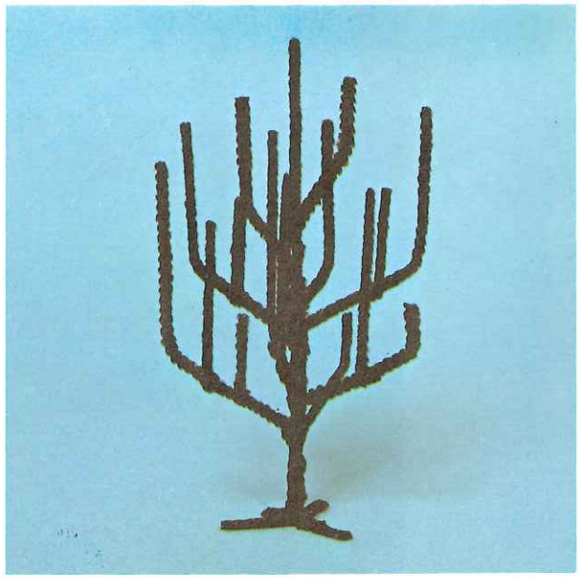


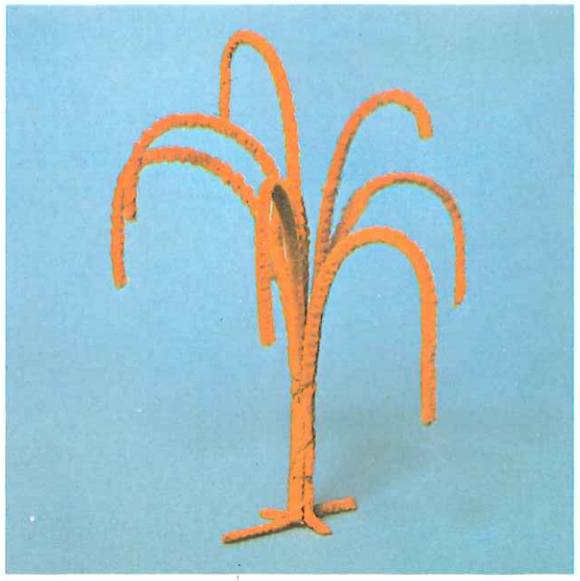
Coral crystals

Supplies: copper sulphate; potassium ferricyanide; large vessel or jar with a wide mouth and a capacity of about 1 litre; pipe cleaners; brass wire; spatula.

Measure the capacity of the jar by filling it with water to within two or three centimetres of the rim. Then pour the water into a kitchen measuring cup and note the volume. With a ruler, measure the total height of the liquid from the bottom of the jar to the surface. This will be the maximum height of the framework that you will now make.

Following the pictures below, assemble the pipe cleaners, using brass wire where needed to give more rigidity—the crystals are going to be heavy. Then prepare a solution. First heat the water to the boiling point (the volume you have noted, less 1/9th). Put the copper sulphate in the jar (50 grams per 100 cm^3 of water). Pour in the very hot water and stir until completely dissolved. If your vessel is about 1 litre in capacity, heat 800 ml of water and dissolve 400 grams of copper sulphate. Place the vessel on a very stable surface.





Then immerse the framework in the solution. If it tends to rise to the surface, hold it down with a small metal object or place a piece of wood over the rim of the vessel and attach the top of the framework to it with a thumbtack or drawing pin. Put a weight on top of the pieces of wood. Do not touch anything for twelve hours. Crystals will form only in certain places.

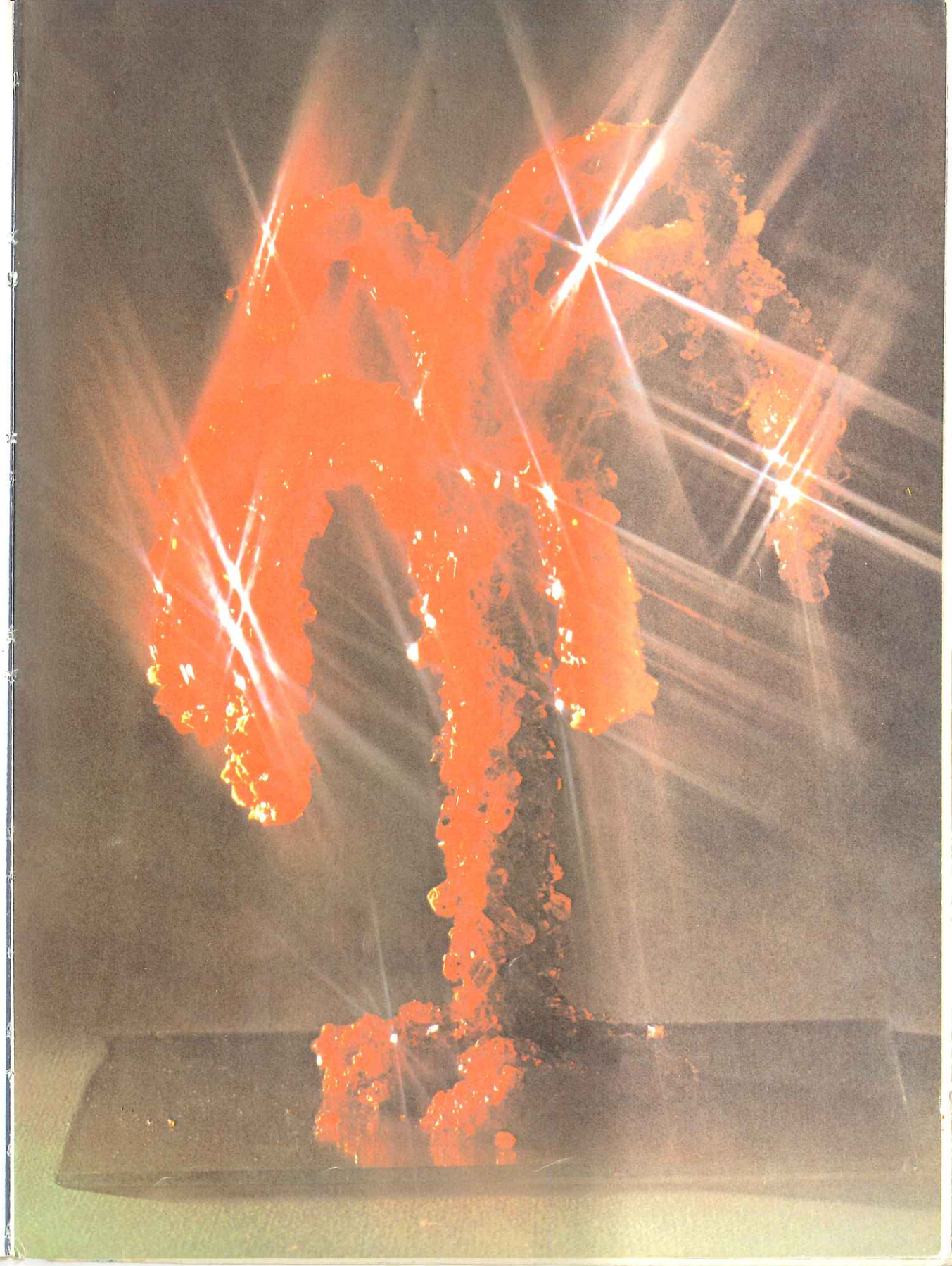
Now precipitate the solution by stirring it with a spatula, without damaging the crystals already deposited. Thousands of tiny crystals will fall like rain upon the framework and will grow until they cover it entirely.

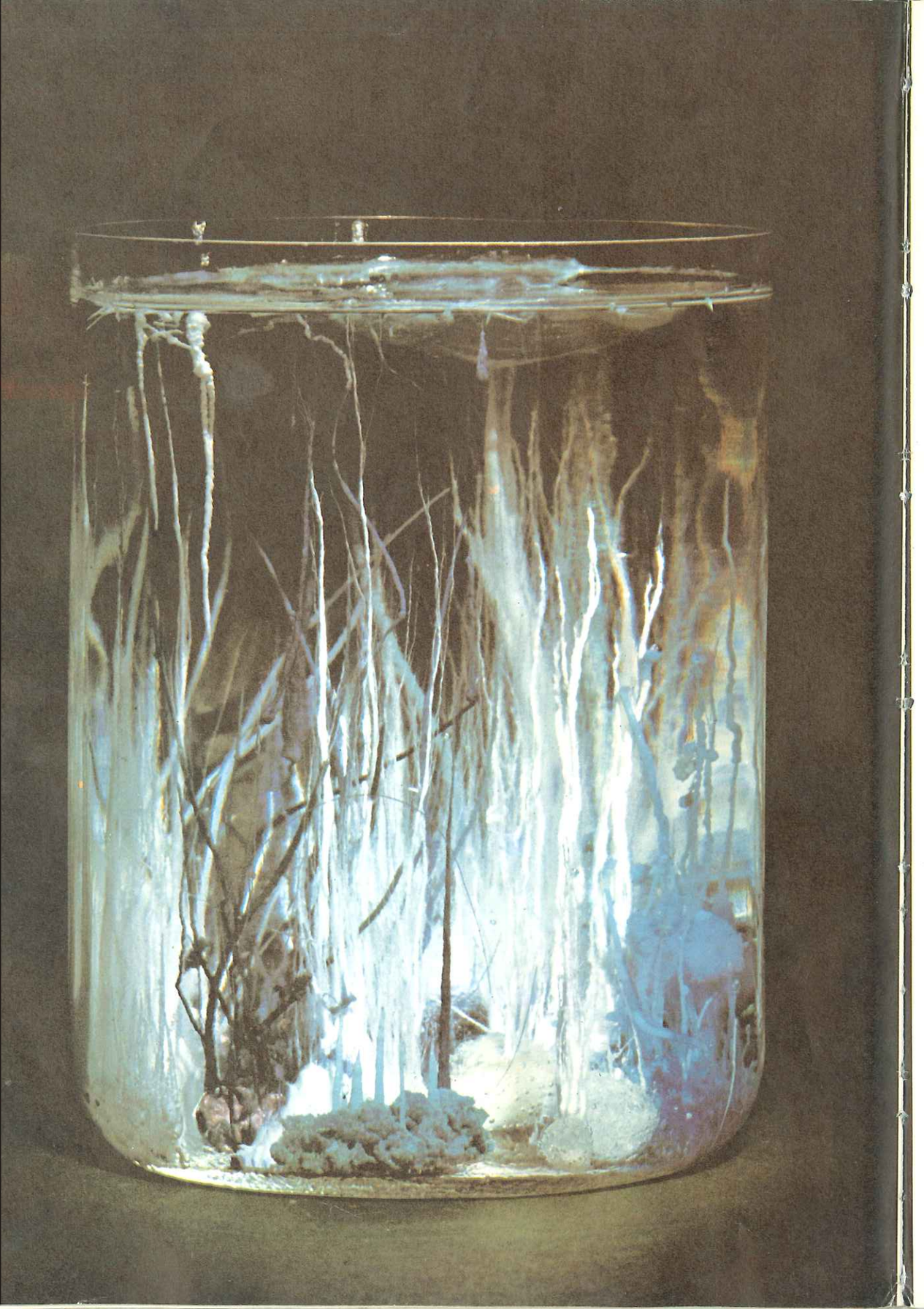
Do not touch for a day and a half. Then, in order to get the coral formation out of the jar, loosen or crush the crystals that hold it to the bottom of the jar with a rod. Remove it carefully. Let it dry out for a while in a receptacle exposed to the air. It will become harder. The red coral (photo on the right) was made in the same way with potassium ferricyanide (50 grams per 100 cm^3 of water). Here the crystallization is much faster and it is not necessary to stir the solution—the crystals grow on the framework from the start. Stop the experiment when the branches have reached the desired thickness.

Be careful not to touch the copper sulphate crystals with your bare hands. Copper sulphate is toxic and can be absorbed through the skin.

Variation: Different-colored corals can be made in a similar way using other substances. Potassium alum will yield white coral, while chrome alum, on the other hand, will give a deep mauve coral. Other frameworks can hold crystals, if the crystals will stick to them. Thus, this terra cotta jug was immersed in copper sulphate solution, like the blue coral on page 34.

□ It is not simply a matter of similar appearance that prompts us to talk of corals. Certain living organisms, such as corals, are really crystal factories. Whole islands have been formed by their work from minute crystals of calcite. But the corals themselves need no prefabricated framework and their crystals are far smaller.





The underwater forest

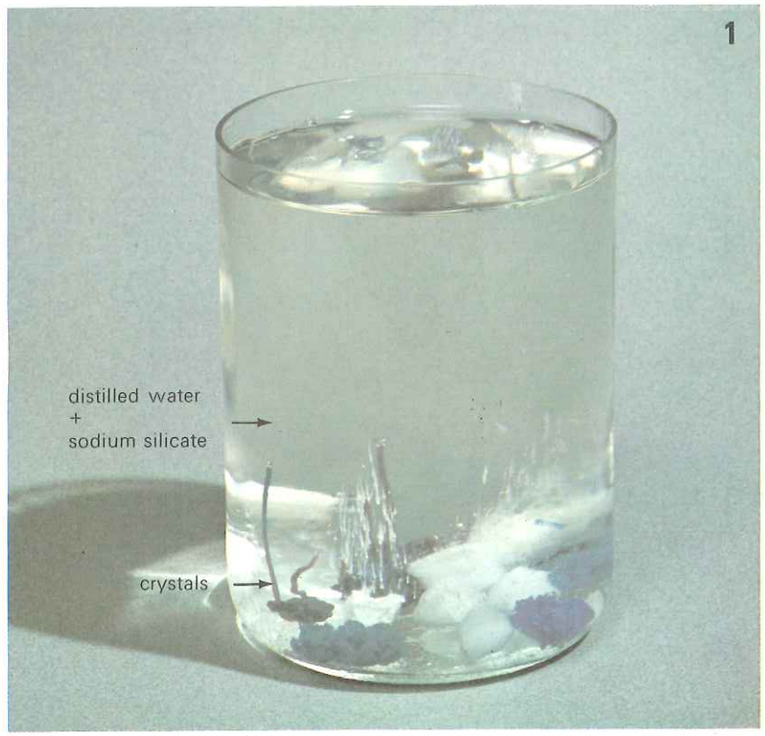
Supplies: 1 litre of sodium silicate (also called *liqueur de cailloux,* literally, pebble liquid), obtainable preferably from a pharmacy; a litre of distilled water; a jar with a capacity of about two litres; large crystals or walnut-sized lumps of the following; copper sulphate, cobalt chloride, calcium chloride, magnesium sulphate, potassium alum, aluminum sulphate.

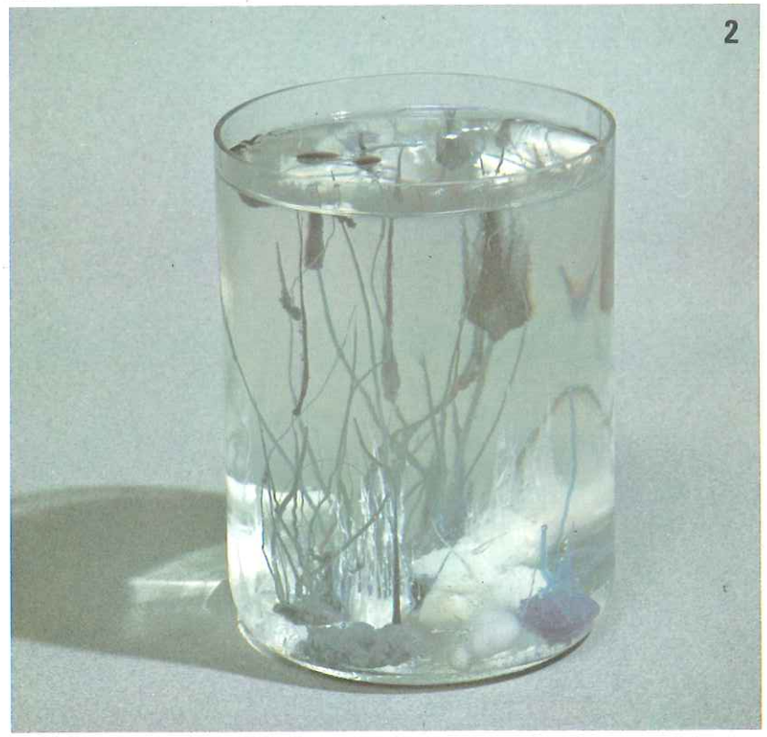
In a very clean jar, pour the litre of silicate diluted with distilled water to the point where the density of the solution is 1.1. For example, if the density of the silicate is 1.3 (or 35° Beaume), add 500 cm³ of distilled water. Stir the solution well until the liquid is clear. Place the jar on a stable surface, safe from shocks or vibrations, and let it stand a few moments. Then drop the various large crystals into the bottom of the jar (Photo 1) and leave it alone.

The rapid growth of crystals is immediate and an hour later your forest is at the point seen in Photo 2. A splendid sight unrolls before your eyes as the forest continues to grow. It will last for a month if your jar is closed and if there are no shocks to break the fragile "vegetation." If you wish to prolong its existence, leave out the calcium chloride, which in time causes the solution to cloud up. Some substances grow for two days, and sometimes for much longer.

The photos displayed on the next two pages as well as that on page 2 show you an aquarium holding 5 litres of solution to which have been added crystals of nickel sulphate (light green), ferrous sulphate (dark green), ferric chloride (large light brown stalk, then the blue one) and strontium nitrate (white). If you have these chemicals, we advise you to use them.

□ The silicate forms semi-permeable membranous sacs around each lump of chemical. The distilled water penetrates the sac, increasing the concentration within it. The concentration becomes so strong that the sac begins to expand rapidly.





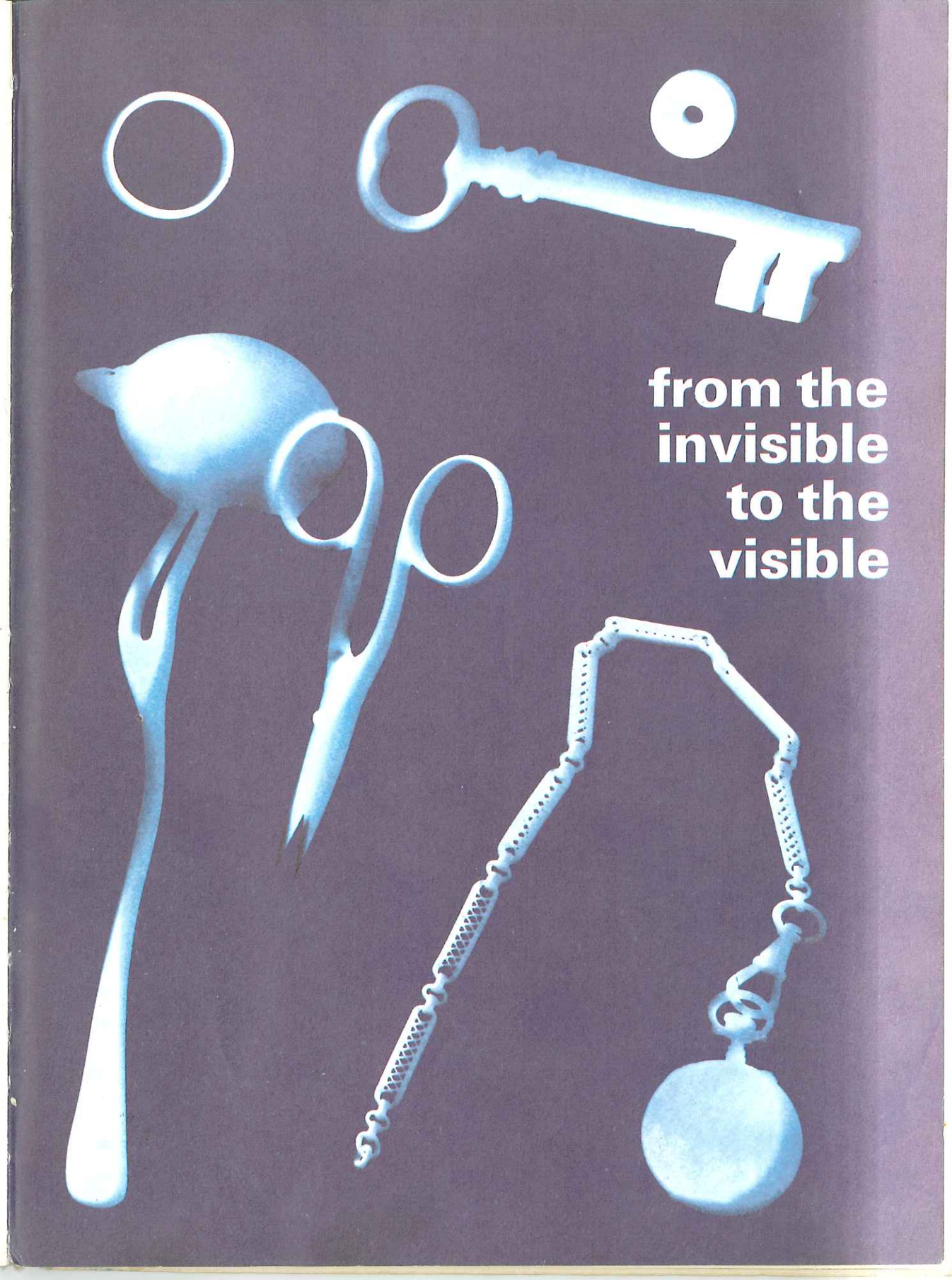
Frost in summer

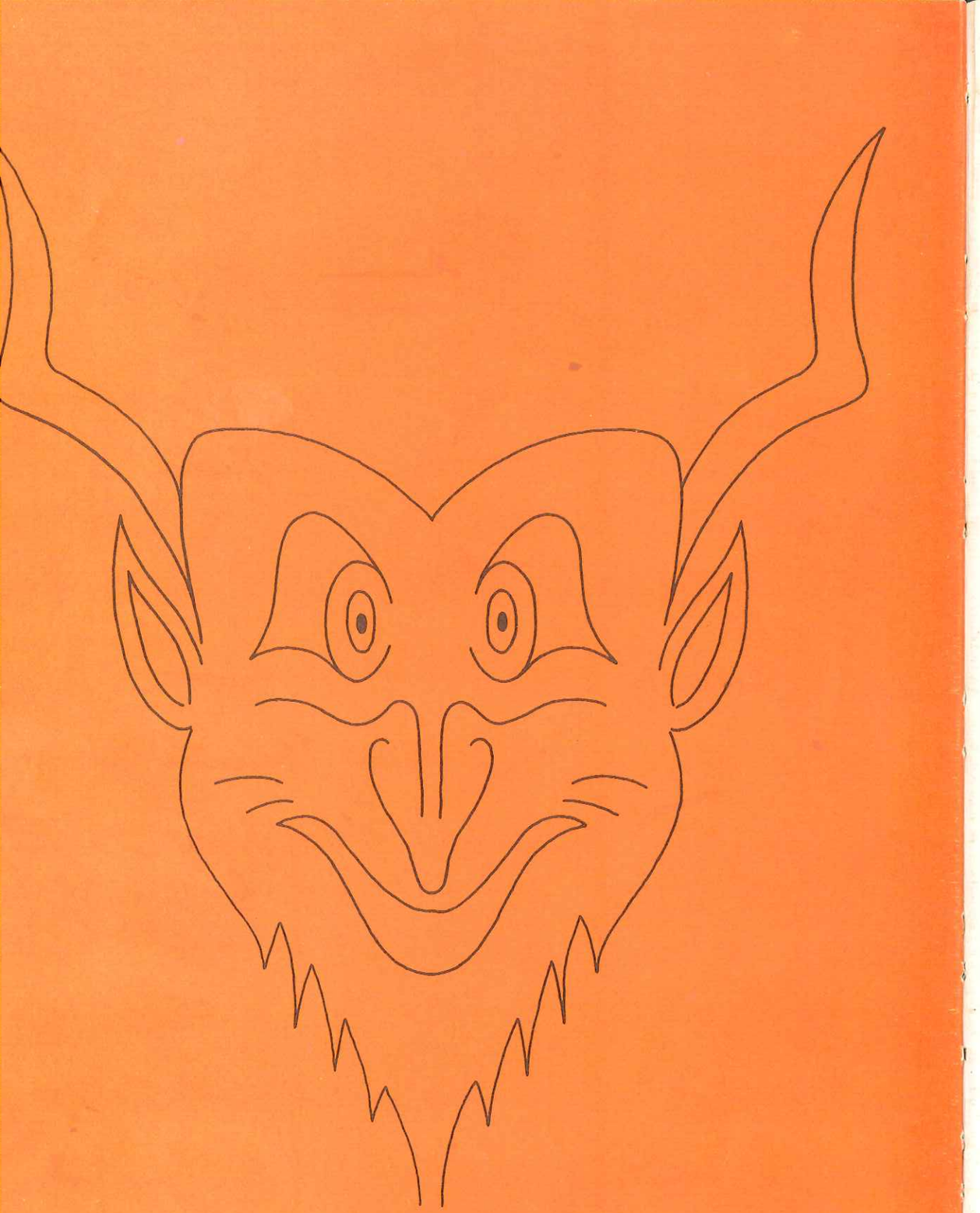
Supplies: benzoic acid (white crystals that form on the surface of vanilla); alcohol lamp and tripod (see page 11); ovenproof glass custard dish; large Pyrex® glass; dried plants; metal wire.

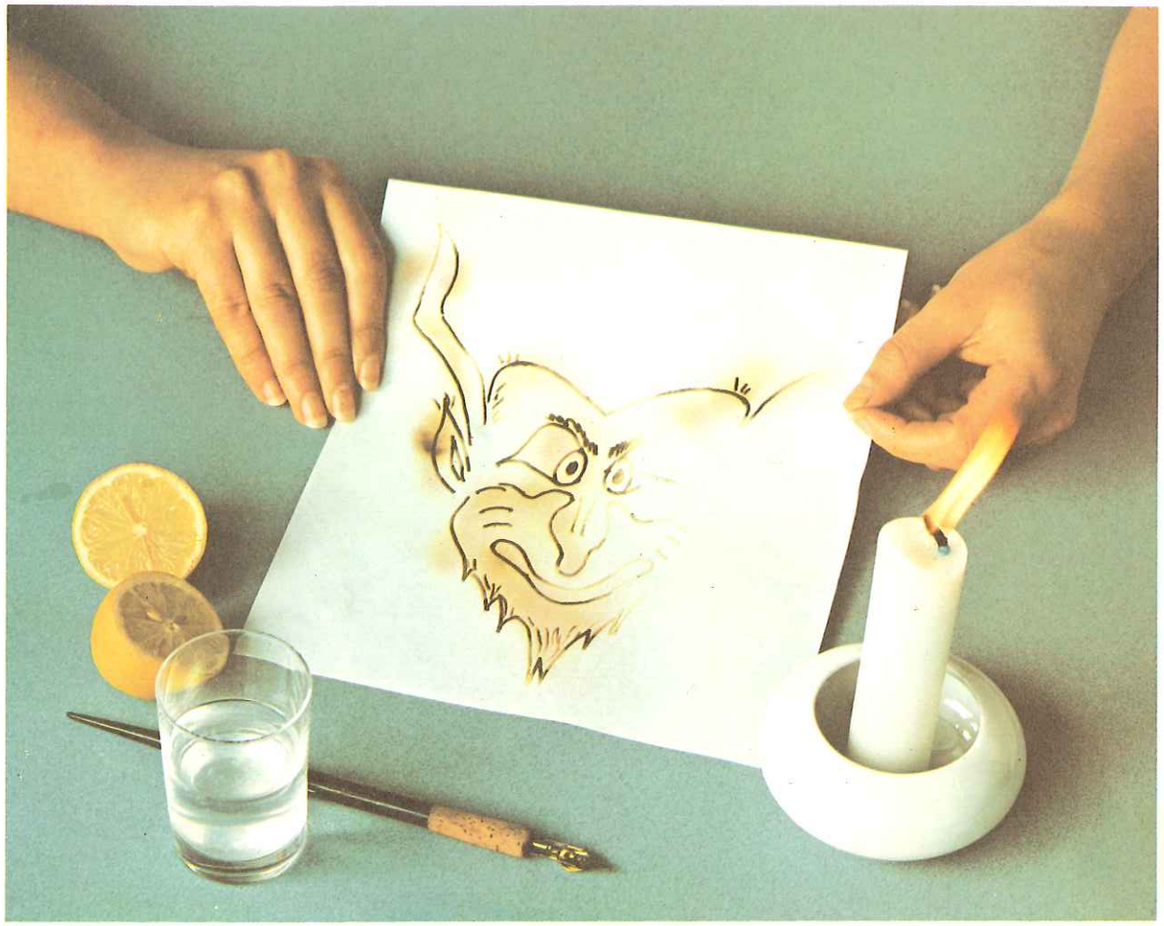
Make a framework out of wire and dried plants. It should stand up firm and straight. Put three tablespoons of benzoic acid in the custard dish at the foot of the "plant," and cover the whole thing with a large glass and place it on the tripod. Then light the alcohol lamp under it: a few minutes suffice to see frost start to form on the plant. It is not necessary to use strong heat.

□ This frost is nothing more than crystals resembling those that form on the branches of trees in winter. The benzoic acid heated by the alcohol lamp gives off vapors that condense in the cool part of the glass forming fine flakes of a pearly color: crystals. Here it is a matter of crystallization by sublimation (the chemical passes directly from the solid to the gaseous state).

47 The mysterious apparition
48 The magic drawing
49 Ultra-secret ink
50 The magic box
50 Phantom writing
51 Heat-sensitive paper
51 Weather indicator
53 Light-sensitive paper







The mysterious apparition

A devil's head appears on a sheet of blank paper when the sheet is held over a lighted candle.

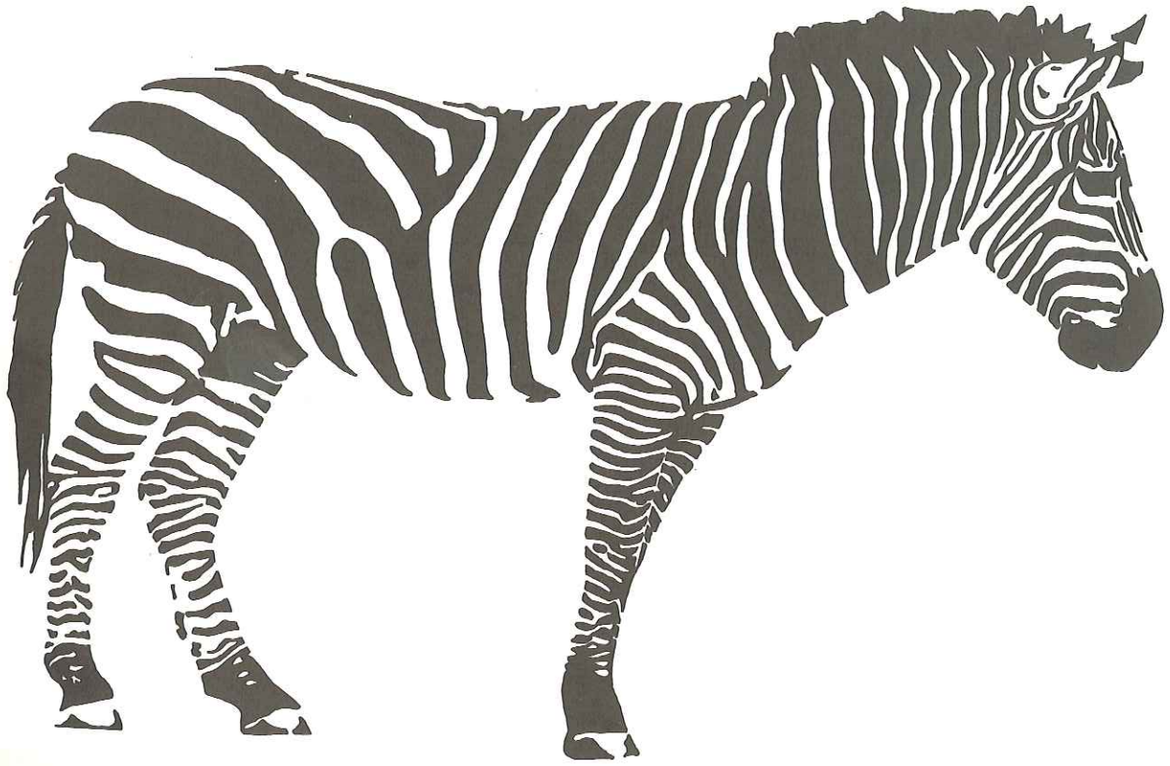
Supplies: a lemon; a lemon squeezer; a glass; a pen (with a palette, if possible) and a pen holder; thin plain white paper; a candle or a steam iron.

Begin by squeezing the juice from the lemon into the glass. Place the sheet of paper over the drawing of the devil on the opposite page and trace it, dipping your pen in the lemon juice. Don't press so hard that you scratch the paper. Let it dry. Your sheet is now ready for the apparition. Pass the paper rapidly over the flame, turning it as you go, until all the lines show up. Or else run a steam iron over it as you would over a piece of cloth. The devil will appear as you see him in the photo above.

Instead of a drawing you can also write secret messages. But don't forget to warn your friends beforehand that they are going to get such a letter and especially to give them a clue to reading the message. Otherwise they will think you are crazy for sending them perfectly blank sheets of paper!

Variations: Instead of the lemon you can use any of the ingredients listed on page 48 to make the devil appear.

□ The lemon juice (citric acid), like all the chemicals or solutions that you will find in the 10 invisible ink recipes on page 48, aids the carbonization of the paper at the point where it has been applied. The sole exception is the cobalt chloride ink: this substance turns blue when the paper is dehydrated by the heat of the candle.



The magic drawing

A zebra appears in blue on a sheet of white paper when a cotton wad steeped in a certain chemical is rubbed over it.

Supplies: cooking water from potatoes or rice (or you can use starch); a glass; a nibbed pen (a *palette*) and a pen holder; thin white paper; iodized alcohol; cotton wad.

Place the sheet of paper on the zebra above and trace it in a colorless ink that is simply the cooking water from the potatoes or rice. You can also use an ink made as follows: dissolve 2 grams of ordinary starch in 100 cm^3 of cold water. Bring to a boil slowly while stirring. Then pour it into the glass. Don't press your pen too hard against the paper or you will scratch it. When you have finished, let the drawing dry. The strokes will have disappeared and your paper will be blank again.

To reveal the drawing, you have merely to run a cotton wad dipped in iodized alcohol over it; the zebra appears in dark blue.

□ The cooking water contains starch, for which iodized alcohol is the reagent. In analytical chemistry, it is used to detect the presence of starch by turning blue.

10 Recipes for invisible ink

Ink	Means of Making it Appear	Color Obtained
1. saliva	rub with cigarette ash	grey
2. lemon juice	candle flame or steam iron	brown
3. onion juice	candle flame or iron	brown
4. 5% sugar solution in water	candle flame or iron	brown
5. milk	candle flame or iron	brown
6. solution of cooking salt in water	candle flame or iron	black
7. saturated solution of potassium alum in water	candle flame or iron	black
8. 5% solution of bicarbonate of soda in water	candle flame or iron	black
9. 5% solution of cobalt chloride in water	candle flame or iron	blue
10. juice of roses, pansies and cherries*	candle flame or iron	black

**Crush together equal amounts of rose, pansy, and cherry petals. To the juice obtained add an equal amount of vinegar and let steep for two weeks before using.*

Ultra-secret ink

A handwritten message or a drawing appears on a blank sheet of paper when it is dipped in water, but disappears when the paper dries.

Supplies: linseed oil; ammonia; distilled water; a small bottle; a nibbed pen and a penholder; ordinary white paper.

Into the bottle, put 100 grams of distilled water (or rainwater), 1 gram of linseed oil (about 10 drops—use salad oil if you cannot get linseed oil), and 40 grams of ammonia. Close the bottle and shake it vigorously. The solution now looks like milk and no trace of the oil remains. If oil is still visible, add a little more ammonia and shake. Your ink is ready, but don't forget to shake the bottle every time you use it.

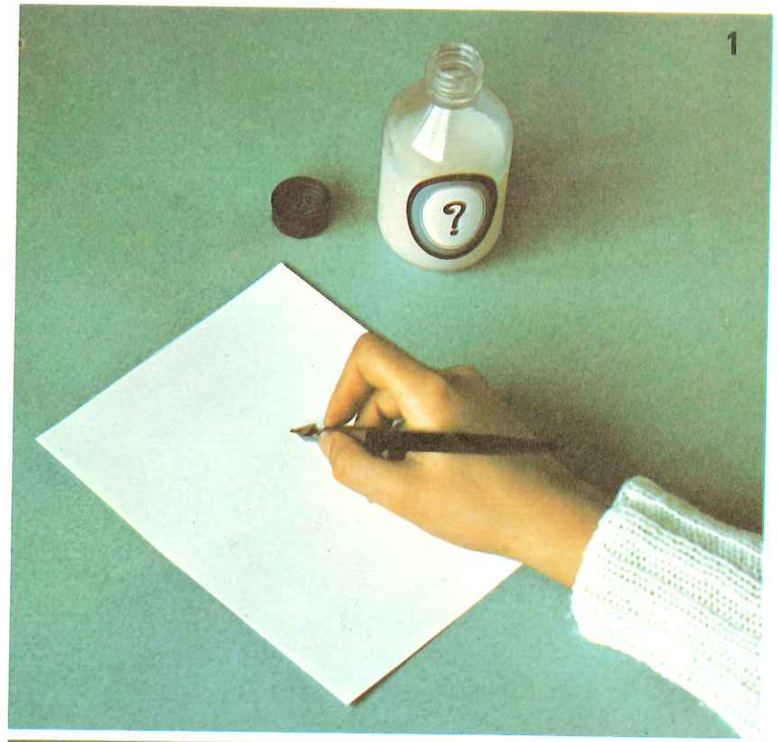
Write or draw, dipping the pen in the solution. Don't press hard enough to scratch the paper (Photo 1). When the ink dries, it becomes invisible and the paper is completely blank. But once you dip it in water, the writing or drawing appears (Photo 2). If you let the paper dry, everything disappears.

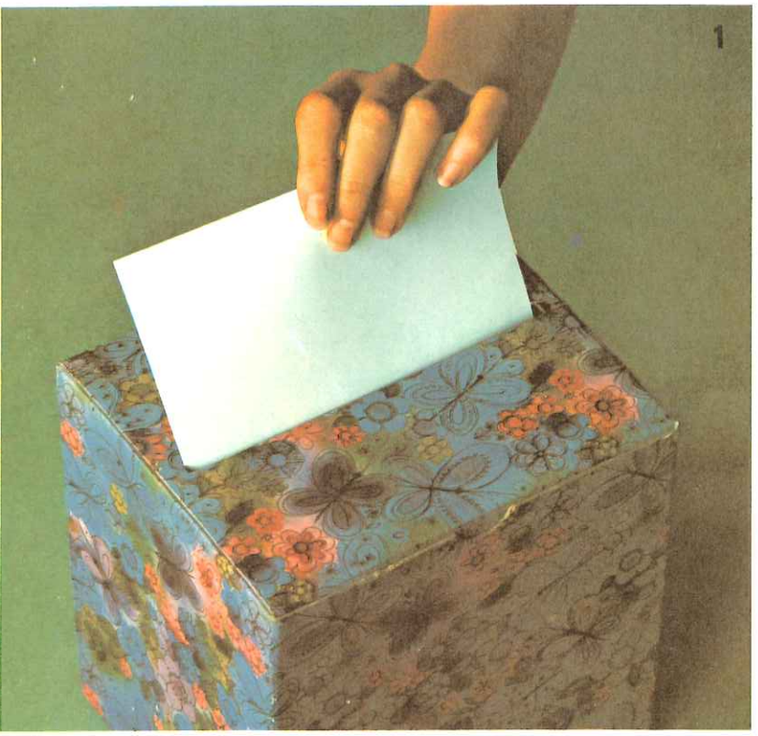
You can repeat this operation as often as you wish. The possibilities of this ink are enough for you to think up numerous games using it. Here, for example, are two ideas.

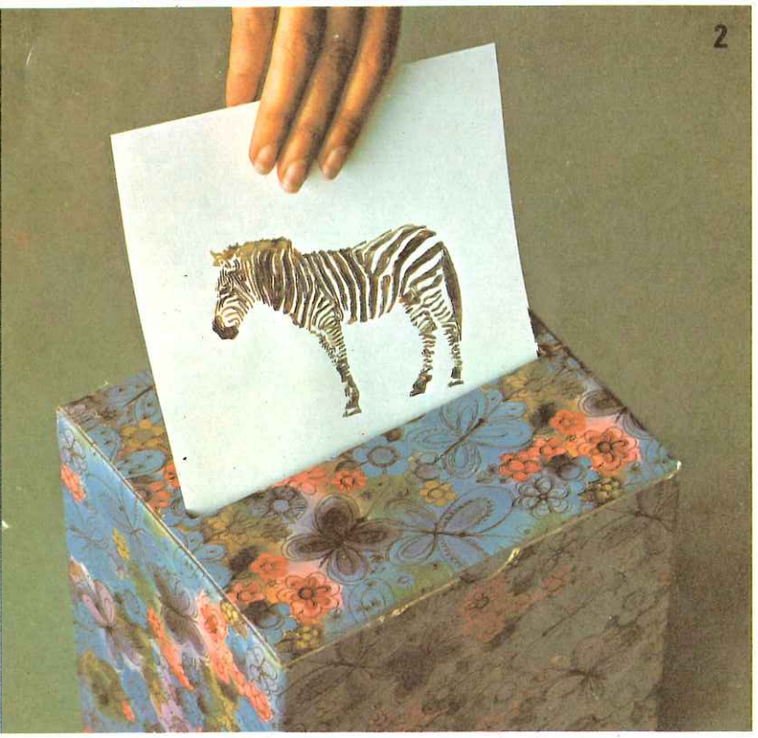
Riddle pictures: Draw a musician playing an instrument—say a bass player, in the normal way, but use invisible ink to draw the instrument. When the drawing is dry, the bass disappears and your friends will have to guess what instrument he is playing. The answer will appear when you dip the drawing in the water.

You can do the same thing with any other occupation.

Question and answer game: Write out a riddle in the normal way on a sheet of paper, and write the answer below it in invisible ink. To find out if they have the rght answer, your friends will have to dip the paper in the water. Once dry, the paper can be used again.







The magic box

A blank sheet of paper is slipped into a slit in a box, and several minutes later, when the paper is withdrawn from the box, it has a picture of a zebra on it.

Supplies: copper sulphate; glass; an artist's paint brush (water-color brush), or better yet, a chicken feather with the point shaved off and split (a quill pen); a cardboard box; a tin container lid; ammonia.

Prepare a copper sulphate solution by dissolving 10 grams of sulphate in 50 cm³ of water. Place the sheet of paper over the zebra on page 48 and trace it by dipping your brush in the solution. Let the paper dry. The zebra disappears.

Make a slot in the lid of the cardboard box. Put the tin lid in the bottom of the box. Put some ammonia in the lid. Now you can slip the paper through the slot (Photo 1) and when you draw it out later, the drawing of the zebra will be revealed (Photo 2).

□ The color that appears is due to the action of ammonia gas on the copper sulphate as the gas escapes from the ammonia solution. A new chemical compound is formed, characterized by a sky-blue color.

If you use a steel pen, some copper will be deposited on it, and consequently on the paper. Therefore, there will be copper on the paper in some places and copper sulphate in others. You will thus obtain the nuances of color that you see in Photo 2 when the picture is revealed.

Phantom writing

Supplies: a fresh egg; a fork; a bowl; black paper; pen and pen holder.

Beat the whole egg for several minutes. Let it stand and beat it a second time. Using this liquid, write on the black paper and let it dry. To reveal your message, pass a hot iron over the paper —it will appear in white. This ink is also sensitive to sunlight. If you expose the paper to the rays of the sun, you will make the message appear.

Heat-sensitive paper

Supplies: cobalt chloride; filter or blotter paper; a glass; a basin.

Dissolve cobalt chloride in water to the saturation point. Put the filter paper in this solution until it is soaked. Then take it out and dry it. It will be pale pink, but over heat it will turn blue.

Variation: Make a solution of cobalt chloride and water, then a solution of ammonium chloride and water. Pour both solutions into a container (the size is not important). Then dilute the solution thus obtained by adding water until it is pale pink. Filter paper dipped into this and then dried becomes almost colorless, but over heat will turn a bright green.

rain **shine**

Weather indicator

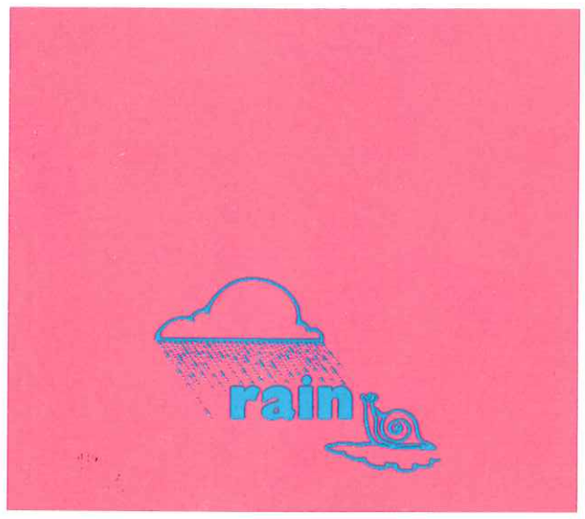
Supplies: gum arabic; a bottle; gauze; cobalt chloride; table (cooking) salt; indelible paint; thick white cardboard (laminated); brush.

Dissolve 3 grams of gum arabic in 30 cm³ of hot water in the bottle. Cork the bottle and let dissolve for 48 hours, then filter it through gauze. Make a second solution by dissolving 30 grams of cobalt chloride and 15 grams of salt in 80 cm³ of water. Filter and then mix it with the first solution. Apply the resulting solution to the cardboard with the brush. Allow to dry in a dry place and apply a second coat. Expose the cardboard to the open air, but not direct sunlight. When it is going to rain or when the atmosphere is humid, it will become pink. With your paint, try to get a similar shade and paint on the cardboard a sunburst and the word "shine," using the large headings provided above.

When the paint is dry, the design will seem to have disappeared. In fair weather, warm or dry, the cardboard becomes light blue: then paint on as before, but using a paint of the same blue tint, the word "rain" supplemented by a little drawing. Your weather indicator is now set up. When it is going to rain, the word "rain" appears in blue on a pink background. The two pictures below show you how it will look.

Variation: Dip a white blotter in a solution made with 30 grams of cobalt chloride and 15 grams of salt. Let it dry. From a picture choose a detail—cloud, flower, dress, etc. Cut the blotter to the contours of the picture, then glue it to the picture. This part of the picture will change color as the weather changes.

□ Sodium chloride (salt) acts as a collector of humidity from the air. The humidity acts on the cobalt chloride. Thus when the air is humid, it turns pink; when the air is dry, it turns blue.



Light-sensitive paper

Supplies: potassium ferricyanide; ferric ammonium citrate (brown); two bottles with caps; writing paper or water-color paper; brush (wash drawing); adhesive tape; glass plate.

Prepare the following two solutions, to be poured into two different bottles:

Solution 1. Completely dissolve 10 grams of ferric ammonium citrate in 50 cm^3 of water.

Solution 2. Completely dissolve 5 grams of potassium ferricyanide in 50 cm^3 of water (Photo 1). Keep the bottles in a dark place. When you use the two solutions, first protect your work table by covering it with old newspapers, then in very dim light mix them in equal quantities in a container (Photo 2).

To sensitize a sheet of paper, daub it with this solution using a brush, or better yet, a tuft of absorbent cotton (cotton wool), attached to the end of a glass tube with an elastic band. The solution is applied in the manner of wash drawings, the paper being held in place by adhesive tape (not thumb-tacks or drawing pins) on a board or glass plate tilted at a 30° angle.

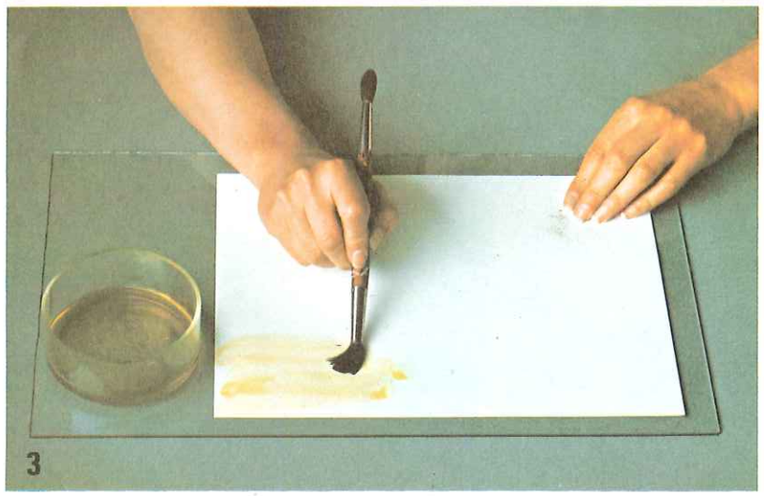
Dry the sheet right away in darkness by laying it flat on its back on a towel.

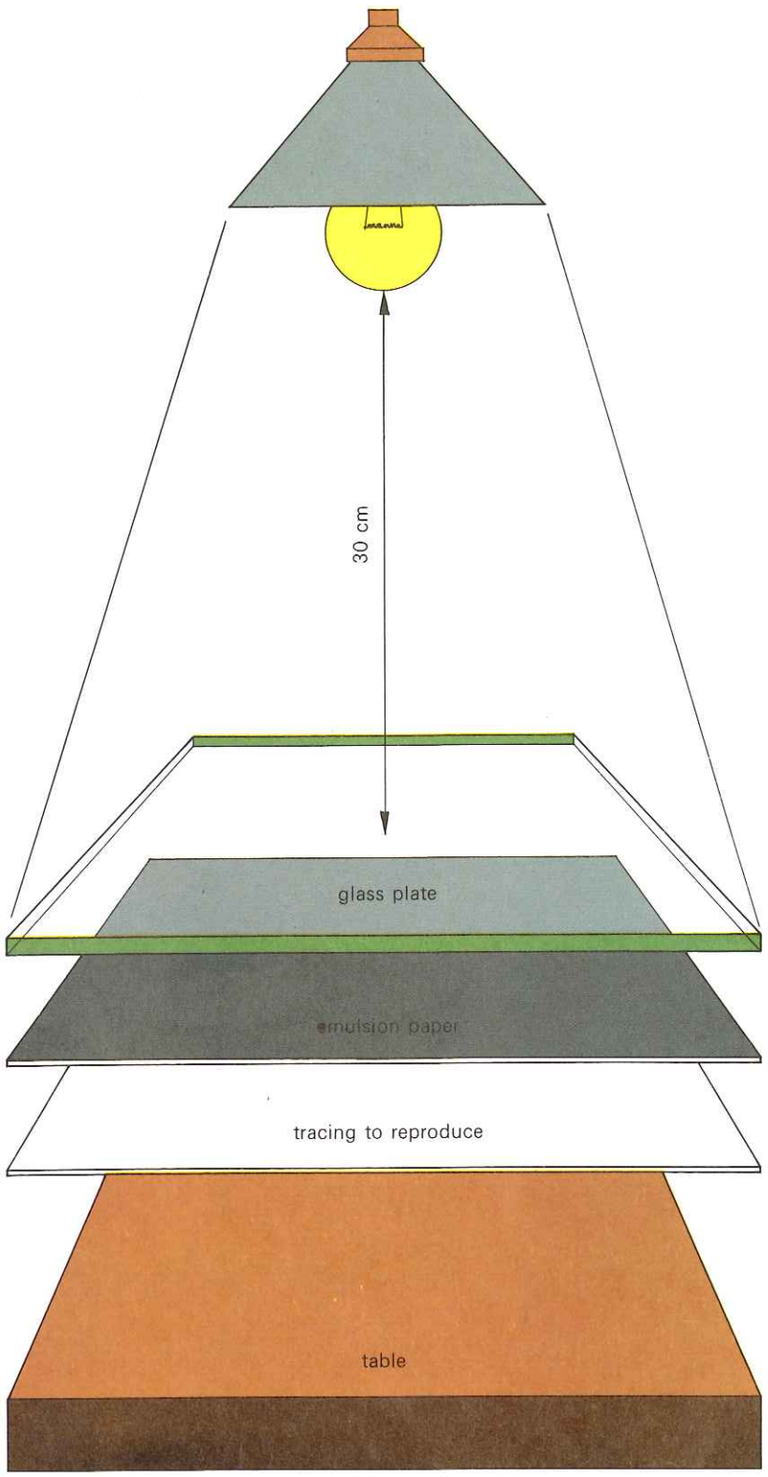
Any object coming in contact with this solution will be tinted blue following the action of light. Also, wash your hands after handling the light-sensitive paper. Stains can be removed by moistening them in a solution of sodium bicarbonate (baking soda) or any ammonia-based household cleanser.

A drawing in India ink on tracing paper, as well as a black-and-white photo negative can be reproduced on this paper.

Place the emulsion-coated paper face-up on a table, then the tracing paper, then a glass plate; expose the whole thing to evenly distributed light—daylight or artificial light (see drawing on page 54). The exposure time can be determined by conducting preliminary tests on small scraps of paper. For example, for a negative of average density, 15 minutes in sunlight; for a photogram (page 52), 10 minutes of sunlight, but 45 minutes of 100-watt lamp light at a distance of 30 cm.

Immediately after exposure, the paper





must be carefully washed under running water for several minutes, then put aside to dry.

The illustrations on pages 45, 52 and 55 were obtained by this process. On page 45, the objects were placed directly on the light-sensitive paper.

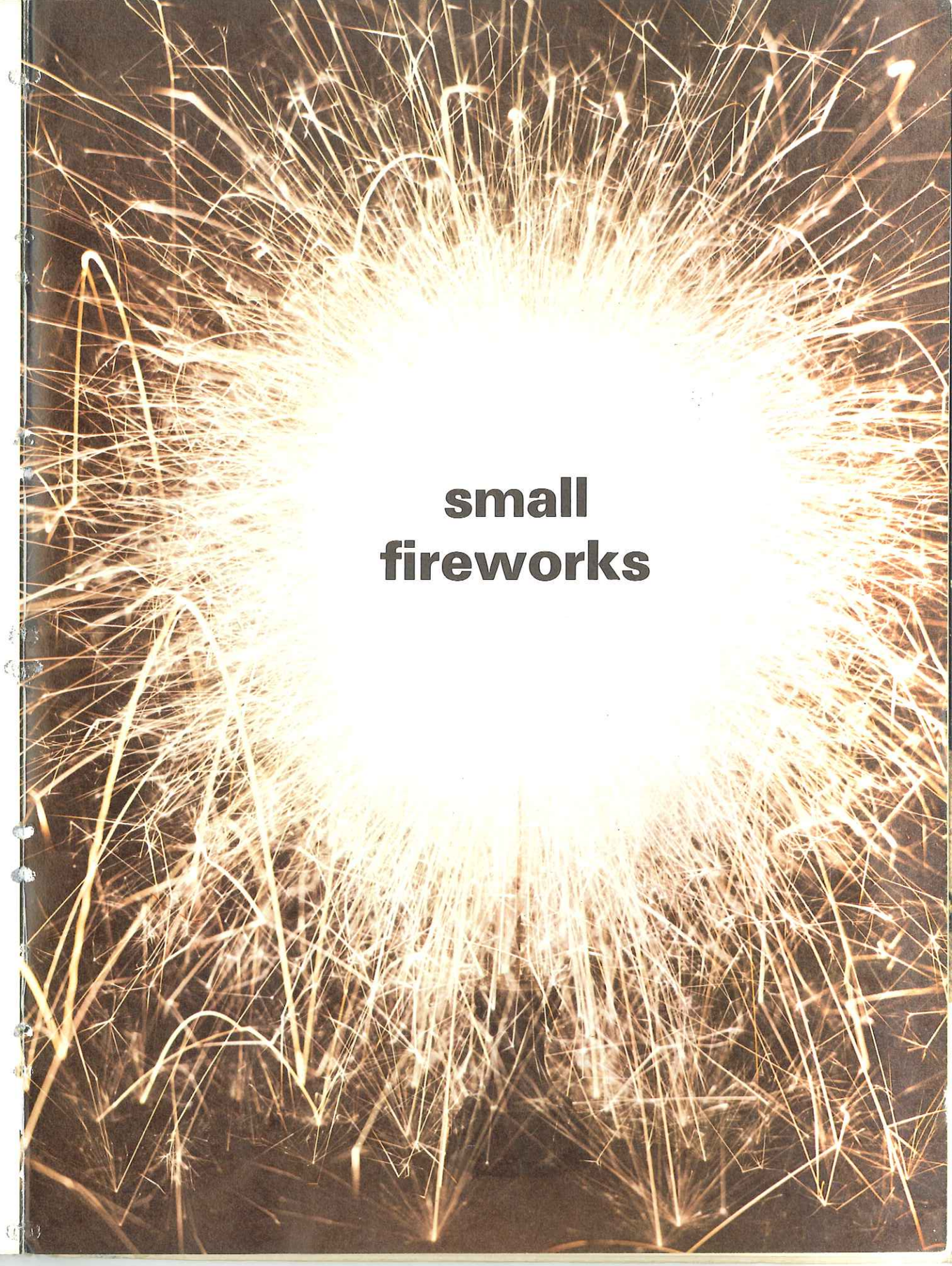
On page 52, some herbs were placed on the paper and then covered with a glass plate.

On page 55, fern fronds and butterfly silhouettes cut out of paper were placed on an emulsion-coated cloth. This solution can be used to sensitize cloth by immersing the cloth in it and thoroughly drying it afterwards. After exposure and washing, iron it gently while damp. This idea will enable you to make some attractive kerchiefs (see photo on opposite page). Use a fine linen or cotton cloth.

For copying black-and-white negatives in halftones, it is better to use negatives with sharp contrast between black and white. If you use green ferric ammonium citrate, you will have faster paper (5 minutes exposure to sunlight instead of 15) and pictures in a brighter blue, but the negatives will have to be stronger than those prepared with brown citrate. In this case, we recommend the following proportions: in 100 cm^3 of water, 8 grams of potassium ferricyanide and 18 grams of green ferric ammonium citrate.

□ We are dealing here with one photographic reaction out of the many that exist. The potassium ferricyanide reacts with the citrate and causes an intense blue precipitate under the action of strong light. The fixing of the proof is achieved simply by washing in water, which dissolves excess sensitizer.

59 Roman candles
61 Magic powder
63 Stromboli
65 Volcanic eruption
65 The forbidden planet
68 Combustible iron wire
68 Colored flames
70 Sugar that flames
70 Pyrotechnics in a thimble
72 Improvised fireworks
72 Fire without matches



small fireworks

Roman candles

Supplies: flowers of sulphur; potassium nitrate; charcoal; iron powder; scales; mortar and pestle; varnish with lacquer base, or if not available, gum arabic base; 20-cm lengths of heavy steel or copper wire; flat receptacle and a spatula; a tall, narrow bottle; piece of expanded polystyrene (Styrofoam®).

Photo 1. Weigh the following substances: 10 grams of flowers of sulphur; 50 grams of potassium nitrate; 15 grams of powdered charcoal; 20 grams of iron powder. To get powdered charcoal break up large pieces and grind them to a fine powder with the mortar and pestle. To these substances you can also add the equivalent of 2 or 3 grams of aluminum powder that you can get by filing a piece of aluminum. Make a homogeneous mixture of these different substances by mixing them with a spatula on a sheet of paper (as a mason does when he makes cement).

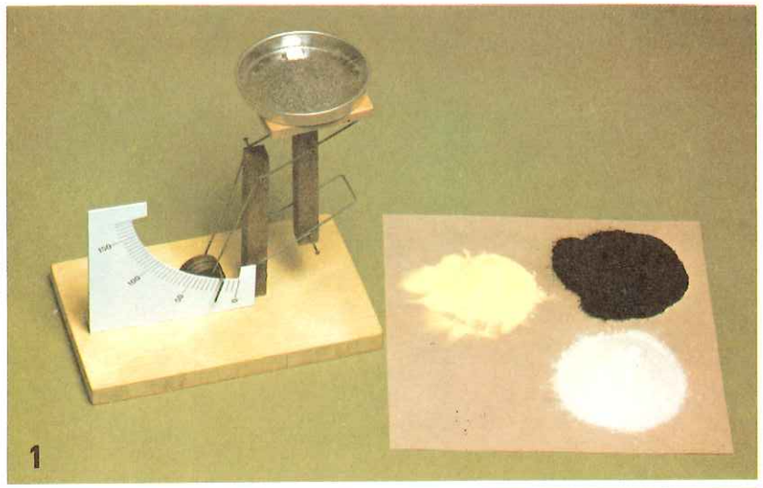
Photo 2. Put mixture in a receptacle and add enough varnish to make a thick, creamy paste. Pour this into a tall, narrow bottle (e.g., olive bottle).

Photo 3. Dip the lengths of wire in your paste, pull them out and let them dry a few moments by sticking their ends in a piece of expanded polystyrene (Styrofoam®). Repeat this operation three or four times until the wires are well coated. When your "candles" are dry forty-eight hours later, you can set them off by heating the tip over a match.

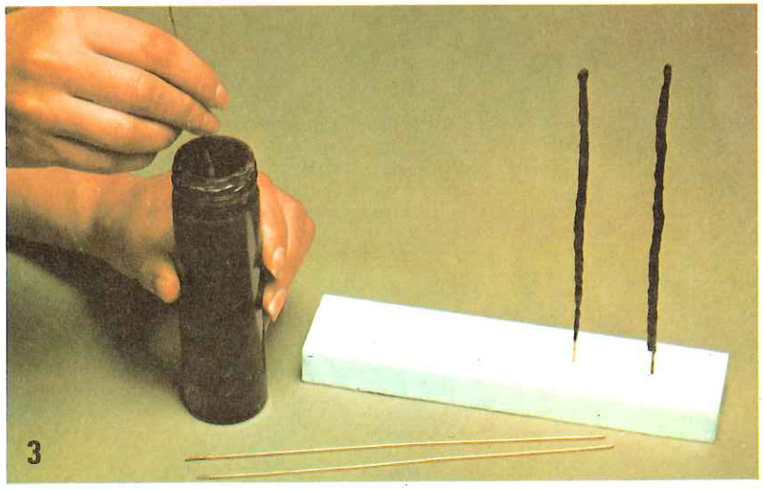
You will find three ideas for making these Roman candles even more spectacular on page 60. All details for making them are included in the drawings.

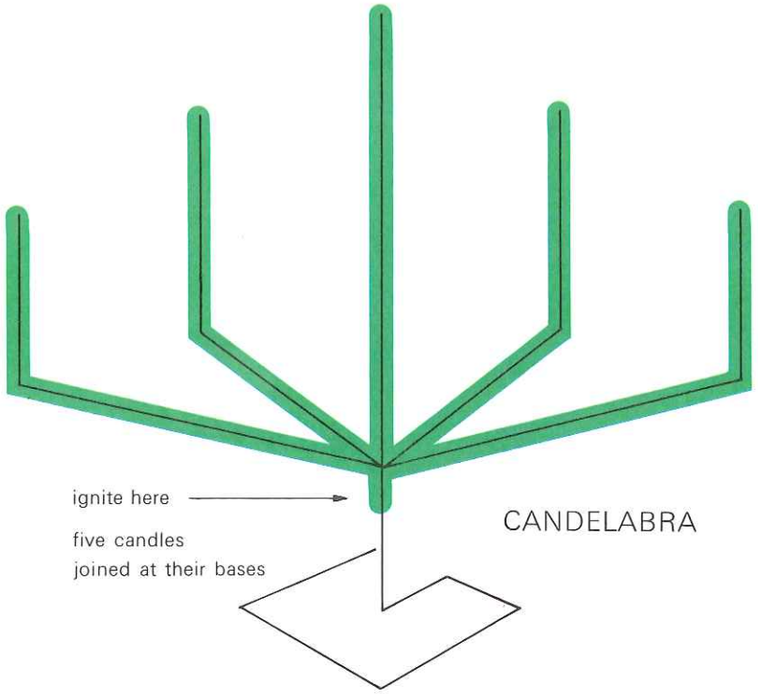
□ Potassium nitrate, heated by a match, releases oxygen and the carbon, sulphur and iron powder then burn, sending off sparks in every direction.

This experiment requires proper eye protection.

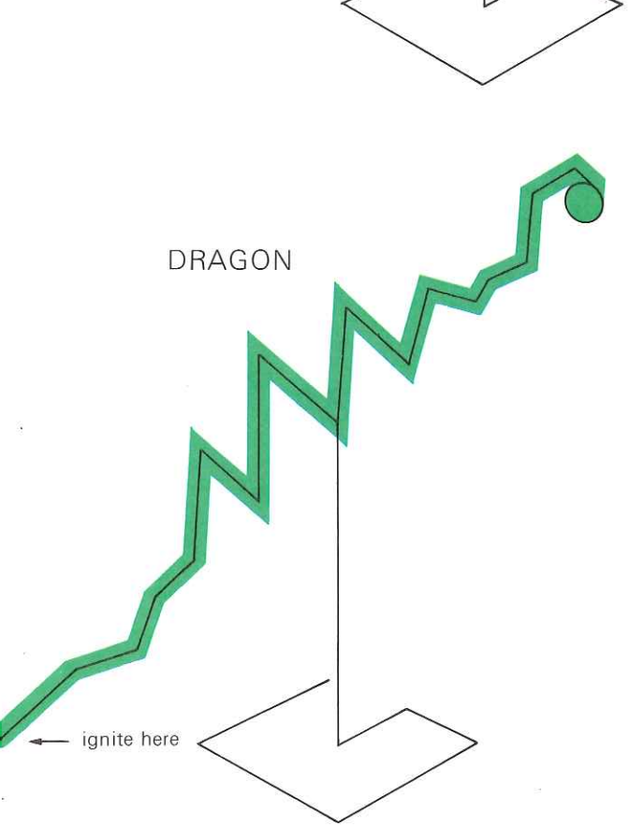

1

2

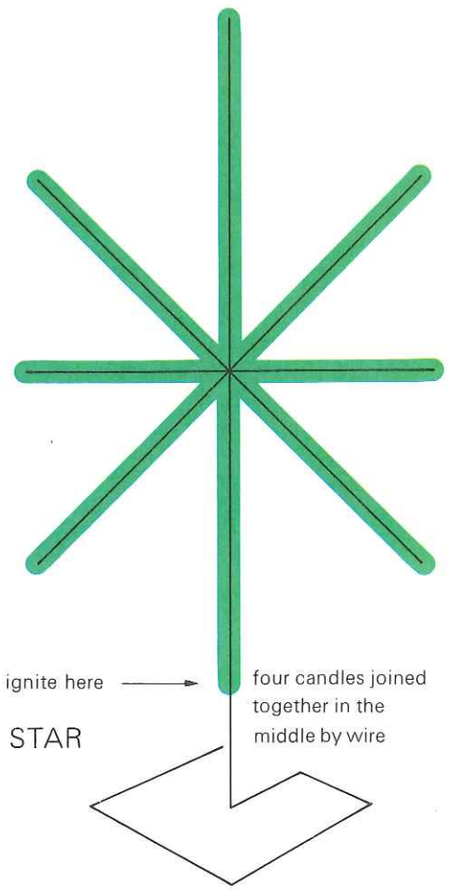

3



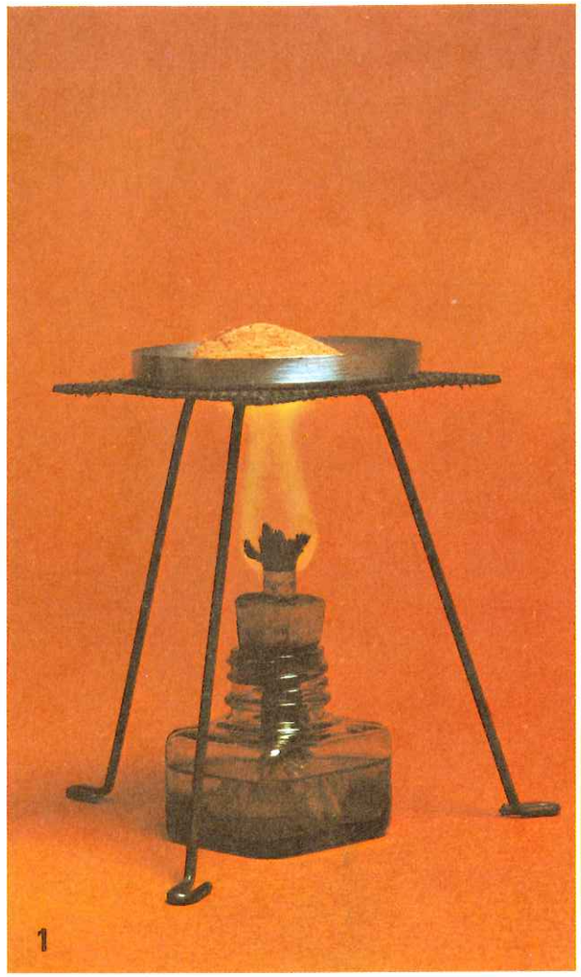
CANDELABRA

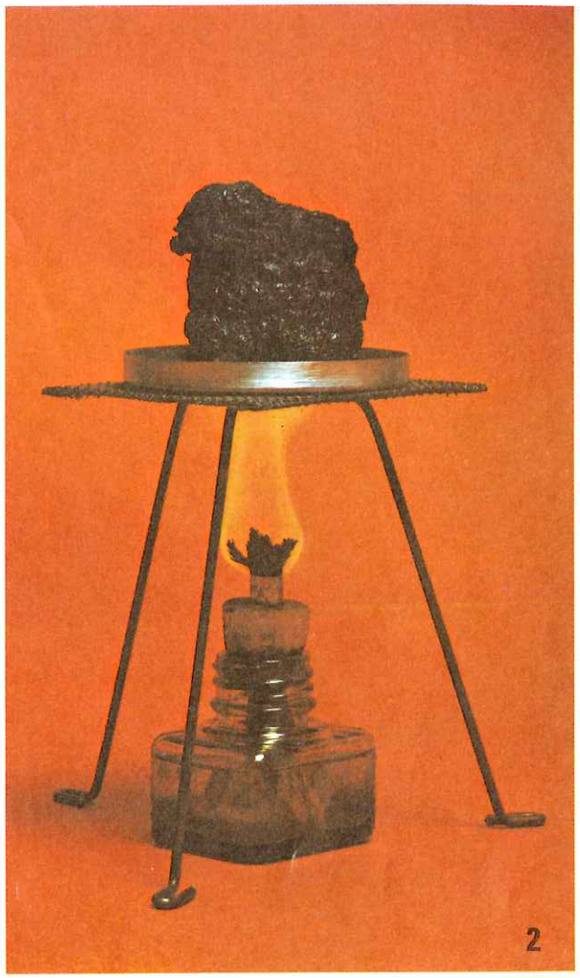


DRAGON



STAR





Magic powder

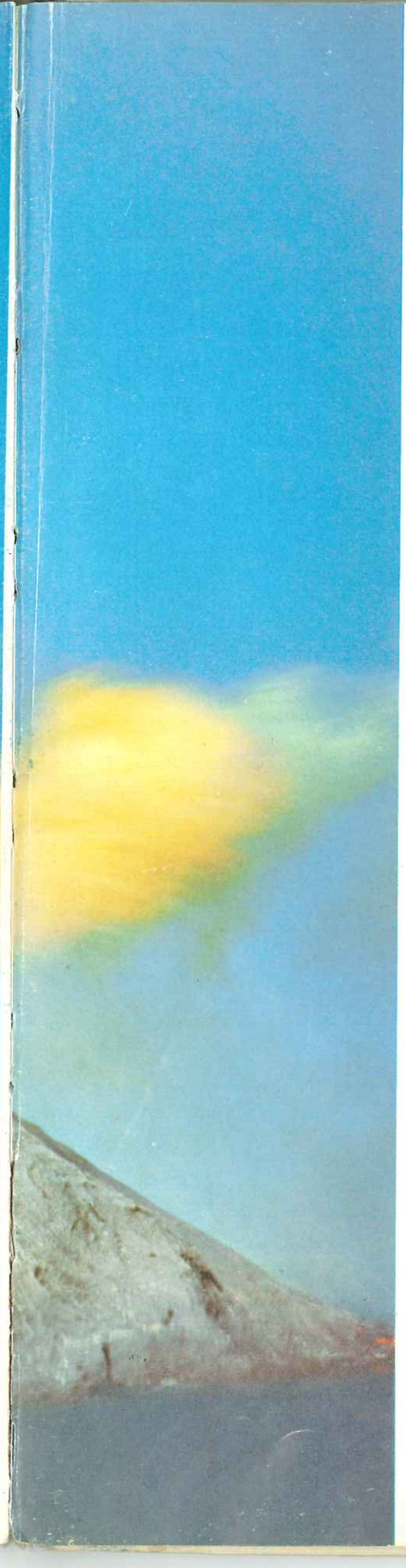
A small pile of powder heated over an alcohol lamp (Photo 1) turns black, swells up, rises before your eyes, and in a few minutes can reach a height of 10 cm (Photo 2).

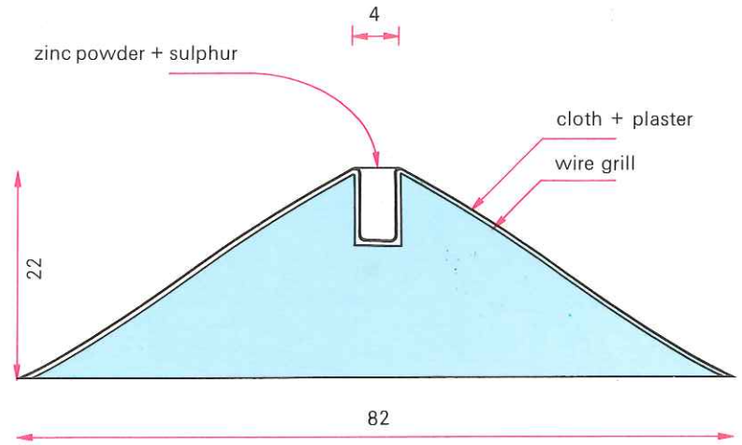
Supplies: cobalt chloride; flowers of sulphur; powdered sugar; tin canister lid; alcohol lamp; tripod; scales.

Weigh 5 grams of cobalt chloride; 5 grams of flowers of sulphur; 10 grams of powdered sugar. The above quantities can vary according to need, but the proportions must be maintained—that is, one part (by weight) of cobalt chloride, one part flowers of sulphur, and two parts powdered sugar. Grind each ingredient separately to a fine powder, then mix them together with a spatula. Put the mixture in the canister lid and heat it over an alcohol lamp (or on the gas range if you put a diffuser between the flame and the receptacle). The mixture begins to swell more and more, rises high above the edge of the lid, and sometimes, when everything is charred, forms a little black "snake" that grows on the top of the pile.

□ The reaction produced by heating this mixture gives carbon and a gas. The gas makes the sugar, transformed into carbon, swell.

This experiment requires proper eye protection.





Stromboli

(experiment for out-of-doors)

Supplies: zinc powder: flowers of sulphur; potassium nitrate; distilled water; filter paper; hexagonal chicken wire; modelling plaster; burlap (hessian); a plastic basin; a soup spoon; lampblack or black vinyl paint; strong scissors or hand shears.

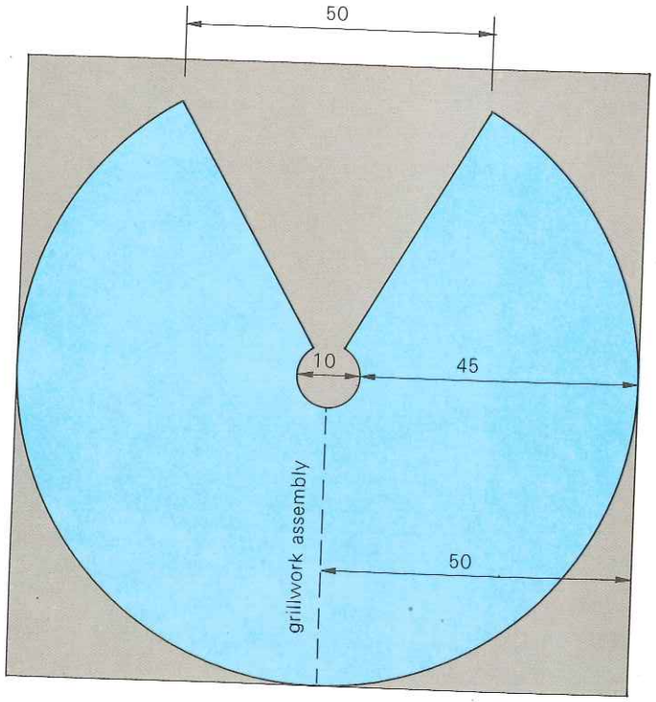
Cut 50-cm-wide strips of wire, enough to form a 1-metre square. Lay out the wire into the form shown in the drawing on page 64. Cut out the center and link up the wire pieces. Make a chimney out of the same wire, about 7 cm deep and attach it to the inside of the top of the cone. Then shape the wire into a volcano, as in the photograph on page 64. Cut the burlap in the same shape as you did the wire, but have it extend about 5 cm beyond the edge of the wire. Mix the plaster in the basin—two parts water to three of plaster. Stir well with the soup spoon and let it stand for two or three minutes. Soak the burlap in the plaster, squeezing it hard to expel air, and immediately place the burlap over the wire cone. Your volcano is now in shape. Fit a small piece of plastered burlap into the chimney to form the crater. The crater should be no wider than 4 cm and from 5 to 6 cm deep. When the plaster has set, let it dry for two or three days.

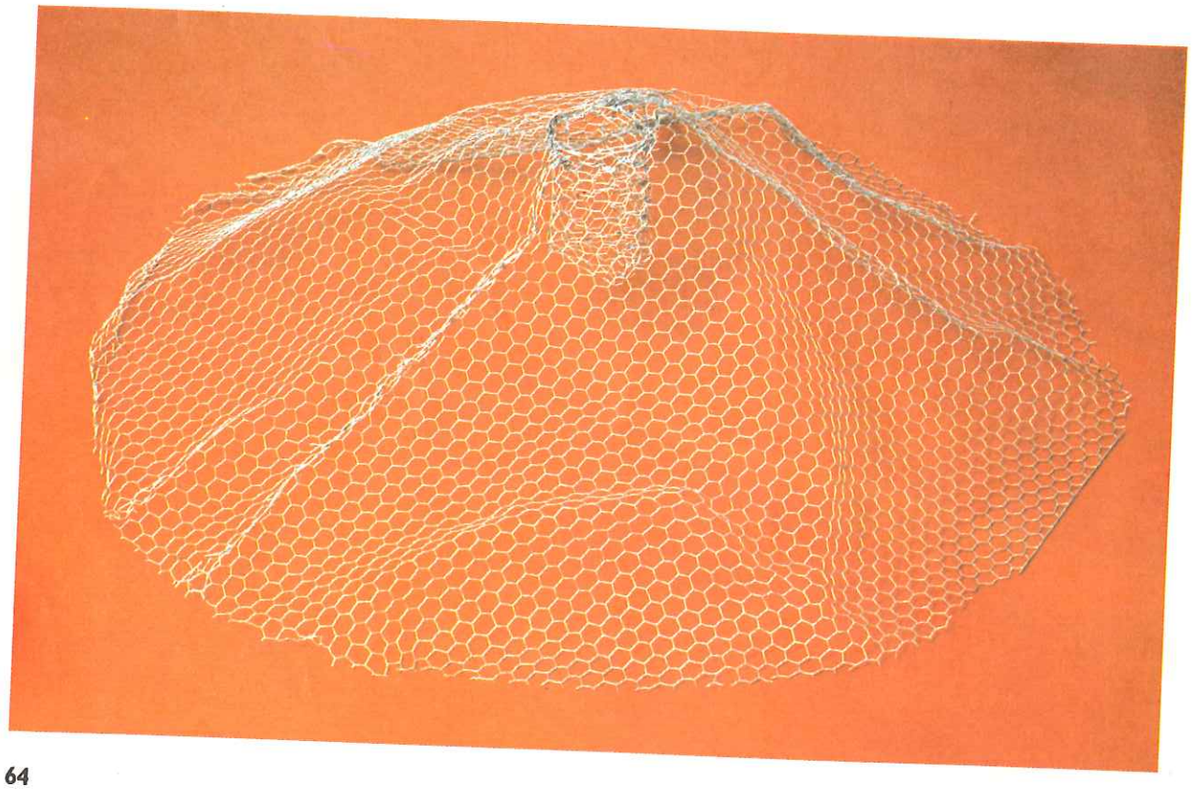
In order to get a more realistic appearance for your volcano, add a good amount of lampblack to the plaster when you mix it or, after it is completely dry, paint the surface in predominantly black or dark green tones.

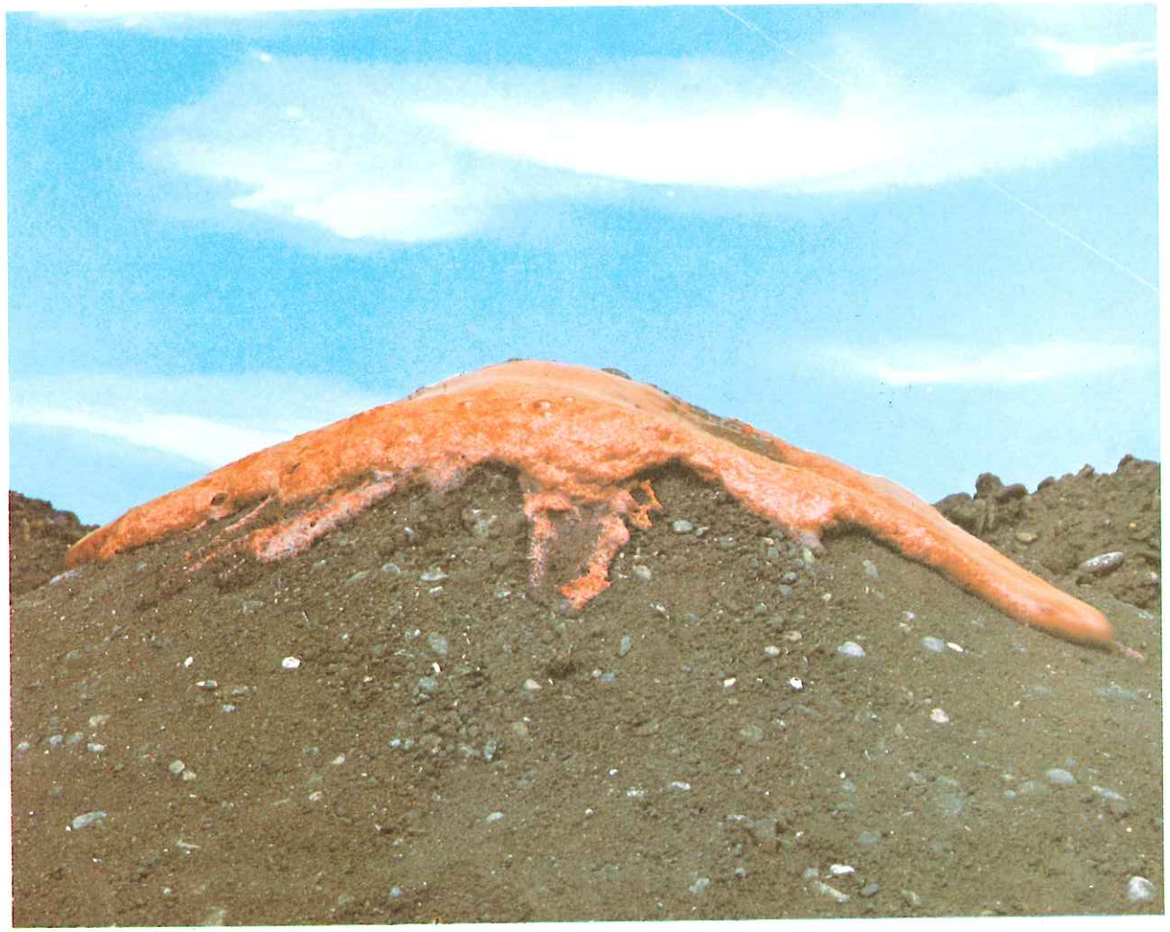
Prepare a wick by immersing a strip of filter paper (or blotting paper) in a saturated solution of potassium nitrate and distilled water (or rainwater) and letting the paper dry. Mix the powder as follows: one part sulphur (by weight) and two parts zinc powder. Place the powder in the crater and stick a small length of wick in it. Then light the end of the wick and stand back.

□ When the wick is lit, the potassium nitrate liberates oxygen which starts the combustion of the sulphur-zinc mixture. The crater then starts to pour forth white fumes of zinc and sulphur.

This experiment requires proper eye protection.







Volcanic eruption

(experiment for out-of-doors)

Supplies: sodium bicarbonate; white vinegar; red paint in powder form; liquid detergent; a small, wide-necked bottle; a 1-litre bottle.

Make a miniature mountain out of soil with the small bottle buried in it, the opening of the bottle forming a crater. Pour the sodium bicarbonate and a little red powdered paint into it. In the large bottle, put 1/4 litre of white vinegar, 1/2 glass of liquid detergent and 1/2 litre of water. To set off the eruption (photo above) pour a little of the mixture into the crater. If necessary, stir the contents of the crater with a stick.

□ The bicarbonate of soda and the vinegar produce carbon dioxide gas (as in carbonated drinks). The lava is formed by detergent bubbles containing carbon dioxide.

The forbidden planet

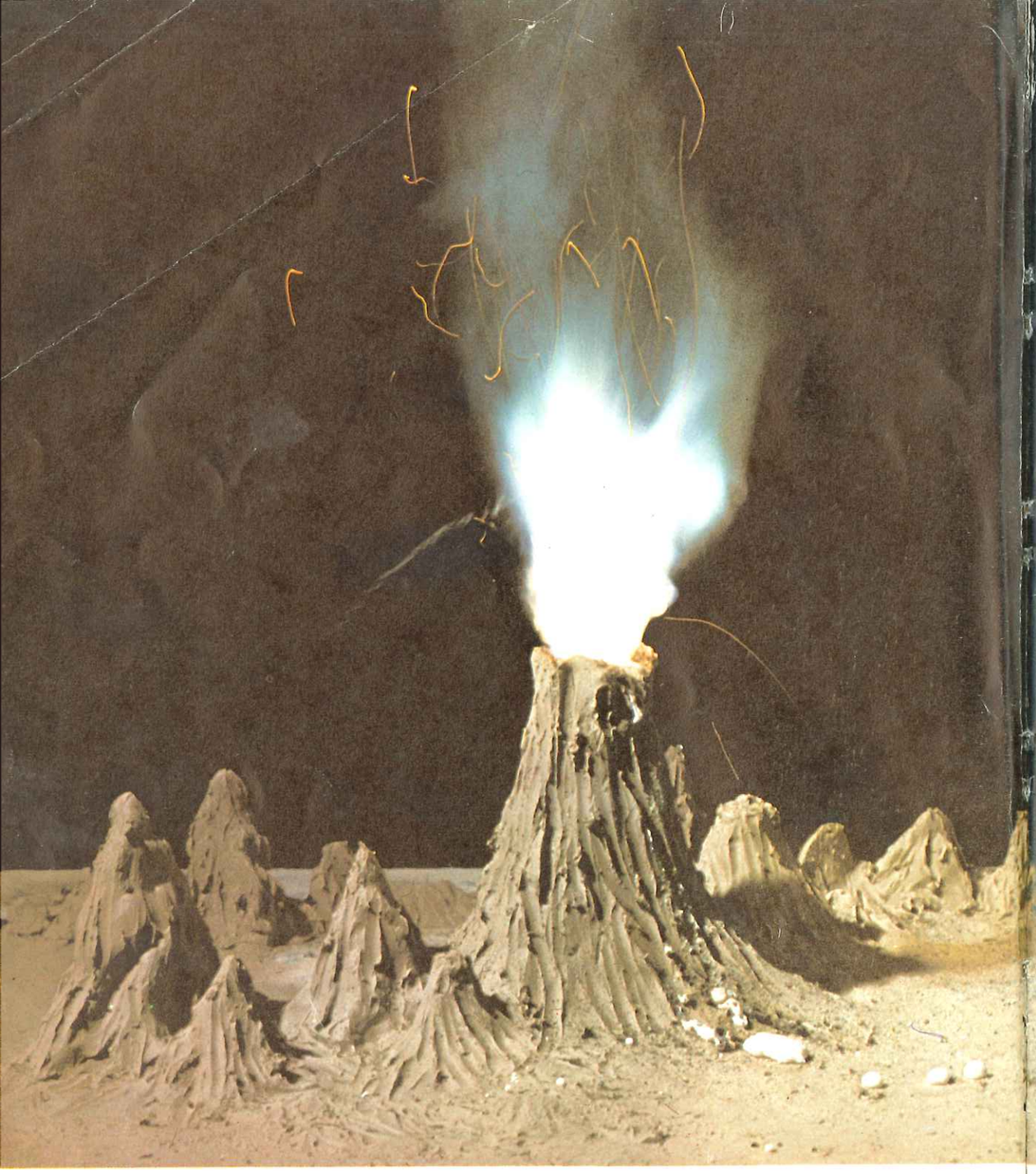
(experiment for out-of-doors)

Supplies: ordinary clay or modelling clay; a board; sheets of paper; scales; potassium nitrate in powder form; flowers of sulphur; wood charcoal; fine table salt; copper sulphate; mortar and pestle; blotting paper or filter paper; distilled water; a spatula.

Using the board as a base, make a volcanic landscape out of modelling clay. The landscape in the photo on pages 66 and 67 measures 90 x 45 cm, and the highest peak is 13 cm high.

To hollow out the craters, stick a broom handle in the clay to a depth of 5 or 6 cm. Allow at least 5 cm thickness between the bottom of the crater and the base.

Mix the powder just before you use it, using one of the three following mixtures (the amounts allow for three or four eruptions each lasting two or three minutes). *White eruption:*



30 grams of potassium nitrate, 10 grams of sulphur, 1-1/2 grams of charcoal. *Yellow eruption:* 20 grams of potassium nitrate, 5 grams of sulphur, 10 grams of charcoal, 15 grams of salt. *Purple eruption:* 15 grams of potassium nitrate, 15 grams of sulphur, 15 grams of copper sulphate.

Weigh the ingredients, place them on a sheet of paper and then mix them with the spatula. To get powdered charcoal, break up large pieces of charcoal with a hammer and then grind them to a fine powder with the mortar and pestle. When thoroughly mixed, fold the paper to make a trough and pour the mixture into the crater.

The ingredients used should be thoroughly dry and as finely powdered as you can get. If some of them are lumpy, break them with the mortar and pestle.

Make wicks by soaking filter paper or blotting paper in a saturated solution of potassium nitrate and distilled water and then drying the paper.

To set off the eruption, insert a piece of wick about 7 cm long into the powder. Light the end and stand back. Wait 10 minutes before starting another eruption so that the crater can cool off.

□ Potassium nitrate when heated by the wick releases oxygen, which in turn causes the sulphur and charcoal to burn. Copper sulphate colors the flame purple and table salt colors it yellow.

This experiment requires proper eye protection.

Combustible iron wire

Supplies: 3/4-litre jar with 2 corks; oxygenated water; sodium bicarbonate; iron wire; filter paper or blotter paper; potassium nitrate or permanganate.

Pour 200 cm³ of oxygenated water into the jar and add 3 tablespoonfuls of bicarbonate. Place the cork loosely on the mouth of the jar and wait for the small bubbles to disappear. Twist a length of wire in a spiral and stick one end in the second cork. Wind a wick round the other end of the wire. The wick is made by soaking filter paper in a concentrated solution of potassium nitrate and letting it dry. Light the wick, quickly remove the cork from the bottle and plunge the wire into the jar.

□ The bicarbonate expels oxygen from the oxygenated water. The wick burns brightly in the oxygen within the jar and brings the wire to the point of incandescence, and sparks result.

Variation: Place 15 grams of potassium permanganate in a Pyrex® test tube equipped with a stopper and a small glass tube and heat over an alcohol lamp. The other end of the tube extends under a wire stand (see page 12) placed in a basin of water. Place a jar filled with water on the stand; oxygen escapes through the tube, rises in the jar and gradually replaces the water.

Stop the procedure when there are only about 4 cm of water left in the jar (this is essential to the success of the experiment). Then, as above, plunge the ignited wire and wick into the jar after quickly removing the cork.

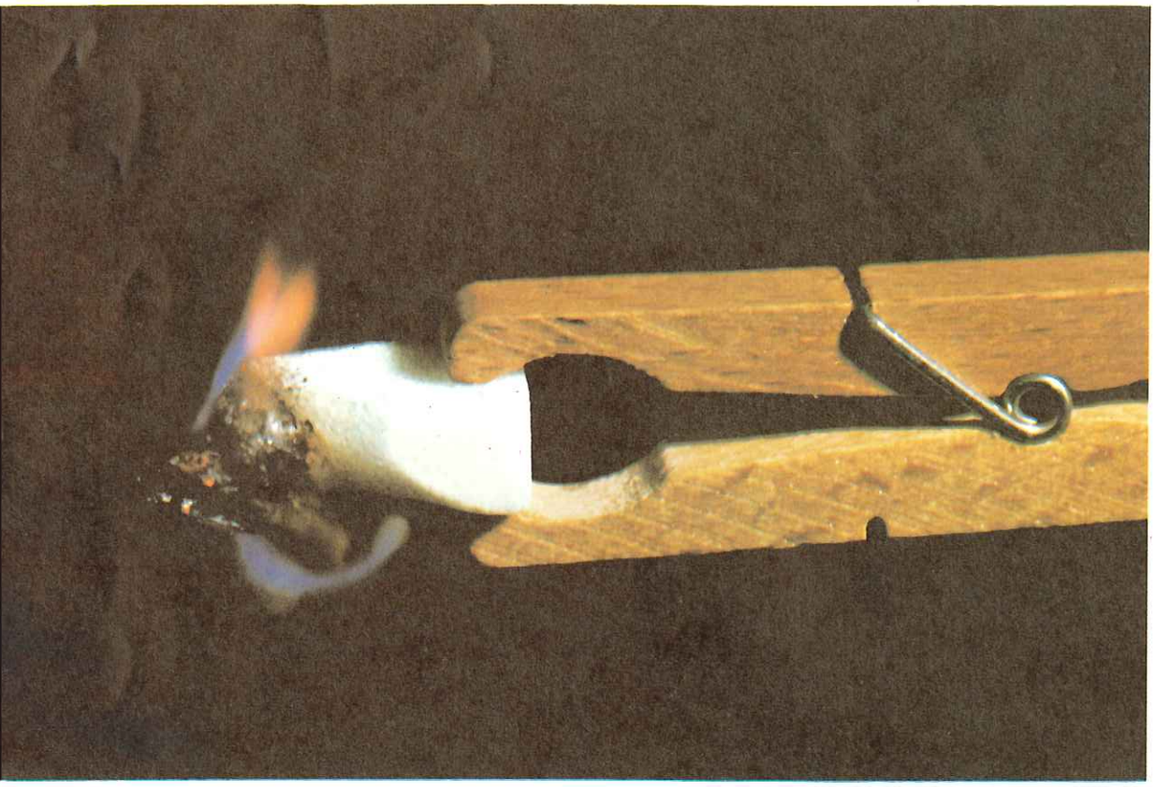
This experiment requires proper eye protection.

Colored flames

Supplies: absorbent cotton (cotton wool); denatured alcohol; wire stand; copper sulphate (green); potassium alum (mauve); potassium ferricyanide (blue); table salt (yellow); calcium chloride (orange).

Dip little wads of cotton in the alcohol; place them on the stand and sprinkle them with very fine powders of the chemicals mentioned above. Then light the wads and turn off the room lights.

□ The different colors obtained represent the reactions peculiar to each chemical and serve to identify it.



Sugar that flames

Supplies: lump or cube sugar; wooden clothespin; candle; cigarette ash.

Have you ever tried to light a cube of sugar? If not, try it as an experiment.

Place a piece of sugar in a clothespin and hold it close to a candle or an alcohol lamp. The sugar browns and melts but does not catch fire. Now, put a bit of cigarette ash on the tip of the sugar cube and bring it up to the flame. Immediately it flames up and burns down to the end with no trouble, as you can see in the above photograph.

□ The cigarette ash serves as a catalyst—that is, by its presence alone, it makes the sugar burn.

A catalyst is a substance that provokes a reaction without being changed itself. After the sugar has caramelized, an analysis would show that the ash has remained unchanged. Yet its presence is necessary if the sugar is to burn. The use of the right catalyst can often considerably improve the result of a reaction. In the metallurgical industry especially, the catalysts used are often jealously guarded secrets.

This experiment requires proper eye protection.

Pyrotechnics in a thimble

Supplies: metal thimble; iron wire; alcohol lamp; potassium nitrate; charcoal; vessel for sprinkling powder (salt shaker, etc.); mortar and pestle.

Break up the charcoal with a hammer and grind it to a fine powder with the mortar and pestle. Then put the powder obtained in the shaker. Twist the wire around the thimble so that it has a tight grip.

Place 2 grams of potassium nitrate in the thimble and heat it over an alcohol lamp until it melts. Then pull the thimble away from the flames a bit and sprinkle its contents with a few shakes of charcoal. The reaction is instantaneous (see photo at right). You can repeat this experiment several times providing you reheat the contents of the thimble each time.

□ Potassium nitrate when heated releases the oxygen necessary for the combustion of the charcoal, which flames up instantly. Potassium nitrate is a combustive, that is, it greatly aids strong combustion in many reactions.

This experiment requires proper eye protection.

Improvised fireworks

Supplies: candle or alcohol lamp; iron powder or filings; shaker (for powder).

Light a candle. Put the iron powder in the shaker and hold it slightly above the flame. You will observe splendid sprays of sparks produced by the combustion of the iron, as seen in the photo at the left.

□ In effect, iron brought to red heat does not burn when it is in a mass, but does burn when it is in tiny particles, as it is here. In the same way, when an ironworker strikes a piece of iron brought to red heat, small particles break off and give sparks of incandescence.

This experiment requires proper eye protection.

Fire without matches

Supplies: potassium permanganate; glycerine; medicine dropper; wire stand (see page 12); lid of a tin can.

Place the lid on the stand. Put half a coffee-spoonful of potassium permangate in the lid. With the medicine dropper, add 4 or 5 drops of glycerine to the powder. After a few seconds, flames appear mysteriously in the lid, as shown in the photo to the right, without any need of a match or cigarette lighter.

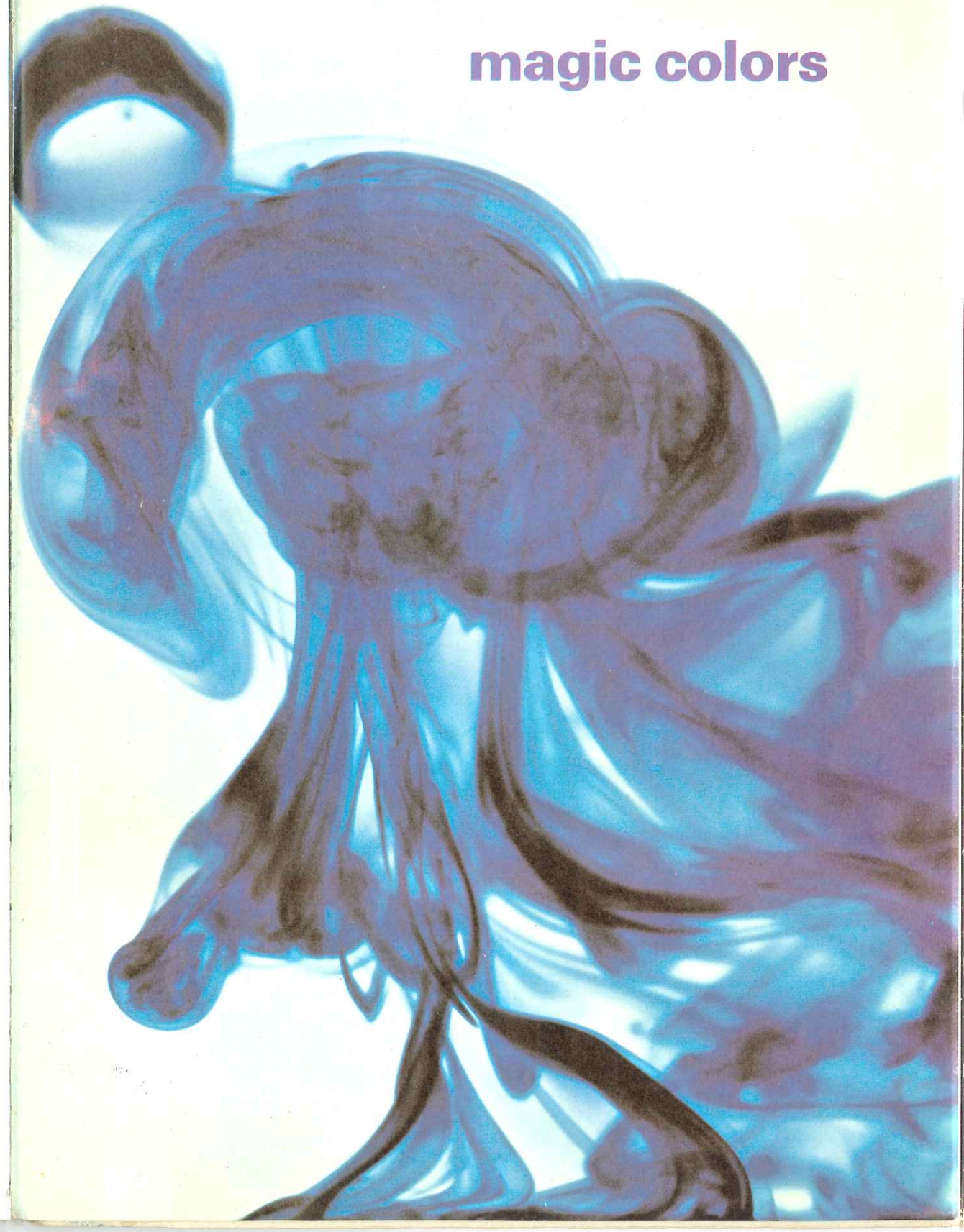
If you heat the lid on an alcohol lamp before adding the permanganate, the reaction will be instantaneous and even livelier. If you don't, it may take nearly a minute to develop.

□ Potassium permanganate quickly oxydizes glycerine, and the heat released forms a flame. Both these substances are often found in the home —the permanganate as an antiseptic and glycerine for skin care. Remember how they react and be extremely cautious when handling these household articles.

This experiment requires proper eye protection.

76 Laboratory enigmas
80 The prestidigitator
80 Liquid chameleon

magic colors



Laboratory enigmas

Five glasses each contain a colorless fluid made by mixing four colorless liquids, each from a different bottle. The game consists of finding out what mixture was used for each glass. Two can play or a contest can be organized with a group of friends. In this case, a leader sets up the glasses in secret and each player in turn, without the others knowing, must discover the contents of the glasses. Each right answer counts one point. Whoever gets all five is named the prize-winning chemist. He knew the right way to analyze a mixture of unknown ingredients, just as professional chemists do.

Supplies: 4 one-litre bottles; 5 tumblers; 3 smaller glasses; 3 small bottles of about 125 cm³ capacity; a lemon; starch; sodium bicarbonate; red cabbage; iodized alcohol; medicine dropper; orange squeezer; saucepan.

Prepare the contents of the 4 bottles: For the red bottle, dissolve 1/4 teaspoon of starch in 1/4 litre of cold water. Heat slowly in a saucepan and stir until it comes to a boil. Pour into the bottle and add hot water until you have a full litre. Let cool. If the liquid is not clear by this time, filter it. For the yellow bottle, dissolve 2-1/2 level teaspoons of sodium bicarbonate in a litre of lukewarm water. If the solution is not clear, let it stand and decant it so that the sediment is left at the bottom. For the green bottle, extract the juice of a lemon with the squeezer and pour it into a litre of water. Filter the solution to make it clear. Simply fill the orange bottle with a litre of plain water.

Prepare the three small bottles: The first (dark brown) is a bottle of ordinary iodized alcohol. The second (red) is a red-cabbage solution obtained in the following way: put pieces of red cabbage in a saucepan, cover with water, bring to a boil, then cook for 20 minutes, until the water becomes a strong violet-red. Let cool. Filter and pour into a bottle. If you do not need all of the fluid, keep what is left over in the refrigerator. For the third bottle, pour in 125 ml of the starch solution from the large red bottle and add iodized alcohol drop by drop until the solution is a dark blue. Label your three bottles with their contents and also put numbers on the 5 tumblers. Now make two charts exactly like those on page 78. The first is for the player who prepares the mixtures and the second for the one who analyzes them. The information on these charts is kept secret throughout the entire game.

bottles → / glasses ↓	3 soup spoons	3 soup spoons	3 soup spoons	to be added
1	NO	YES	NO	YES
2				
3				
4				
5				

table to record preparation of glasses

bottles → / glasses ↓	iodized alcohol turns blue	red cabbage turns blue	blue solution loses color	no reaction
1	NO	YES	NO	YES
2				
3				
4				
5				

table to be filled in by "researcher"

Rules of the game: The first player is the only one to fill the five glasses. He does this as he sees fit. However, he must take the equivalent of 30 cm³ from each bottle, except for the orange, which he uses to fill up the glasses so that they are even in content. The glasses should all be filled to about 120 cm³. The first player notes his arrangements on his own chart, and puts the four bottles out of sight of the other player. The second player returns to the room. He must now, using the three small glasses, a teaspoon and the three small bottles, determine the contents of each glass and mark it on his chart.

Solution of the game: According to the rules, you know that each glass contains some liquid from the orange bottle, perhaps exclusively from that bottle, if you do not detect the presence of one of the solutions from the other bottles. It is now up to you to discover the presence of one, two, or three other solutions in each glass. Take the first glass and pour two teaspoonfulls of its contents into each of the three small glasses.

Photo 1. Put several drops of iodized alcohol into the first small glass. If the liquid turns bluish, the glass contains starch from the solution in the red bottle. If it takes on a slight yellow tint, or stays clear, you know that it does not contain starch. Enter the results on your chart.

Photo 2. In the second small glass, place a teaspoon of red-cabbage solution. If the liquid becomes bluish, the glass contains sodium bicarbonate from the yellow bottle. If on the other hand, it keeps the violet-red color of red cabbage, you know that it doesn't contain this. Enter your results.

Photo 3. In the third small glass, put a teaspoon from the "starch + iodized alcohol" bottle. If the contents of the glass lose color and become clear, it is because this glass contains lemon juice from the green bottle. If, however, it keeps its blue color, you can be sure that it does not. Enter your results.

Continue in this way with the contents of the other large glasses, being careful to rinse your small glasses and your spoon between each test.

□ The substances in the three small bottles are reagents. They make it possible to detect the presence of another substance in a solution even if it is present in very small amounts. These substances have a precise reaction only on the substances that they are used to detect. Iodized alcohol, thanks to the iodine it contains, made it possible to discover the starch in the solution from the red bottle. Iodine is the reagent for starch. When these two substances are present, the liquid always becomes dark blue. But the iodine has no effect on the color of either the bicarbonate or the lemon juice. Red cabbage is one of many natural coloring materials that change color through the action of the sodium bicarbonate contained in the solution in the yellow bottle (we use the term *base* for substances that have similar properties such as sodium bicarbonate, potash, chalk, ammonia, etc. All of these bases turn the red cabbage solution blue). Finally the starch-and-alcohol bottle was to reveal the presence of Vitamin C (ascorbic acid) contained in the lemon juice from the green bottle.

The prestidigitator

We now change water into wine and wine into cider—not drinkable, of course.

Supplies: three glasses; a small amount of potassium permanganate; oxygenated water; a bottle.

Setting up the glasses: The first one is empty; the second contains a piece of crushed potassium permanganate; the third contains a teaspoon of oxygenated water.

Photo 1. Pour plain water from a bottle into the first glass.

Photo 2. Pour the contents of the first glass into the second; the water is changed into wine.

Photo 3. Pour the contents of the second glass into the third; the wine becomes fizzy cider.

□ The permanganate is a powerful coloring agent. It colors the water in the first glass red. In the third, the oxygenated water reacts with the permanganate and gives it the color of cider and bubbles.

Liquid chameleon

A violet liquid becomes successively red, purple, blue or dark green.

Supplies: Red cabbage; white vinegar; household ammonia; medicine dropper; filter paper; round bottom flask or large glass; saucepan.

Half fill the flask with a red-cabbage solution (see page 77 to make this). Then add an equal amount of water—the liquid is violet in color.

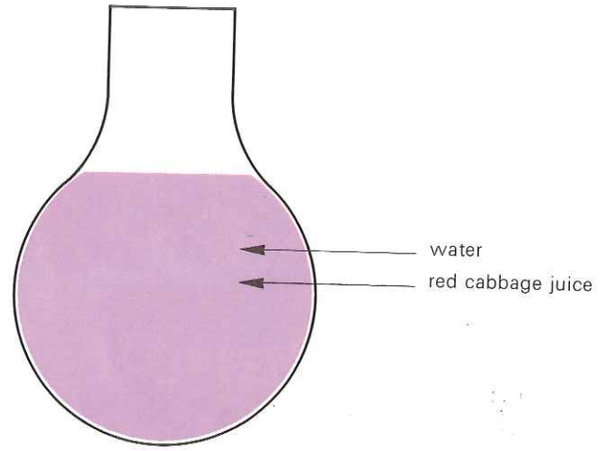
Photo 1. Add several drops of vinegar —the liquid turns red.

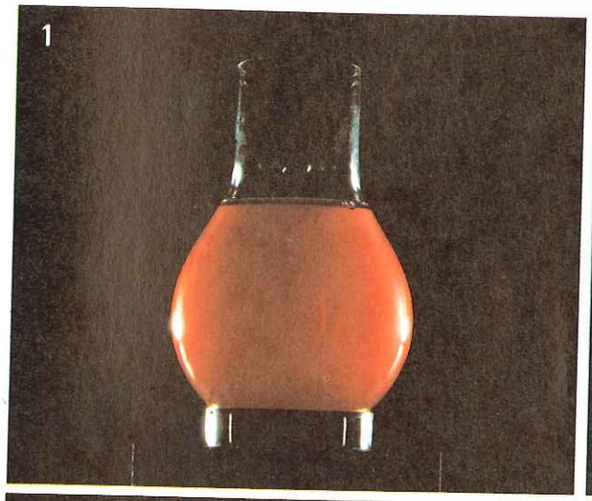
Photo 2. Add several drops of ammonia —the liquid turns purple.

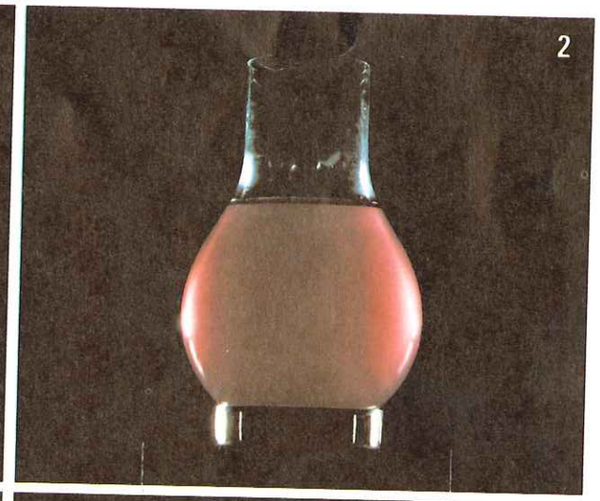
Photo 3. Add more ammonia—the liquid becomes blue.

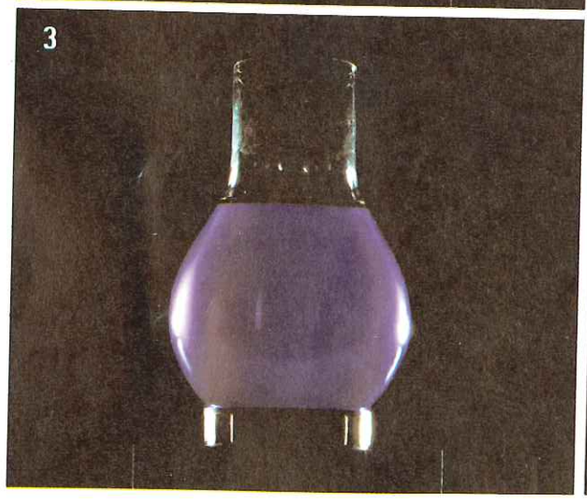
Photo 4. Keep adding ammonia—the liquid turns deep green.

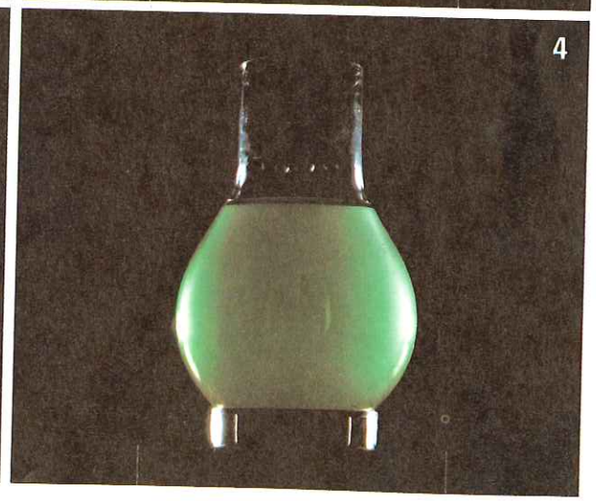
□ Red cabbage juice is a coloring material that changes color when acted upon by an acid (vinegar) and a base (ammonia). Bases are substances with common properties—for example, they destroy acids. Thus the red cabbage juice, reddened by the vinegar, is made violet again by the ammonia, which destroys the acid and therefore can make the solution blue.





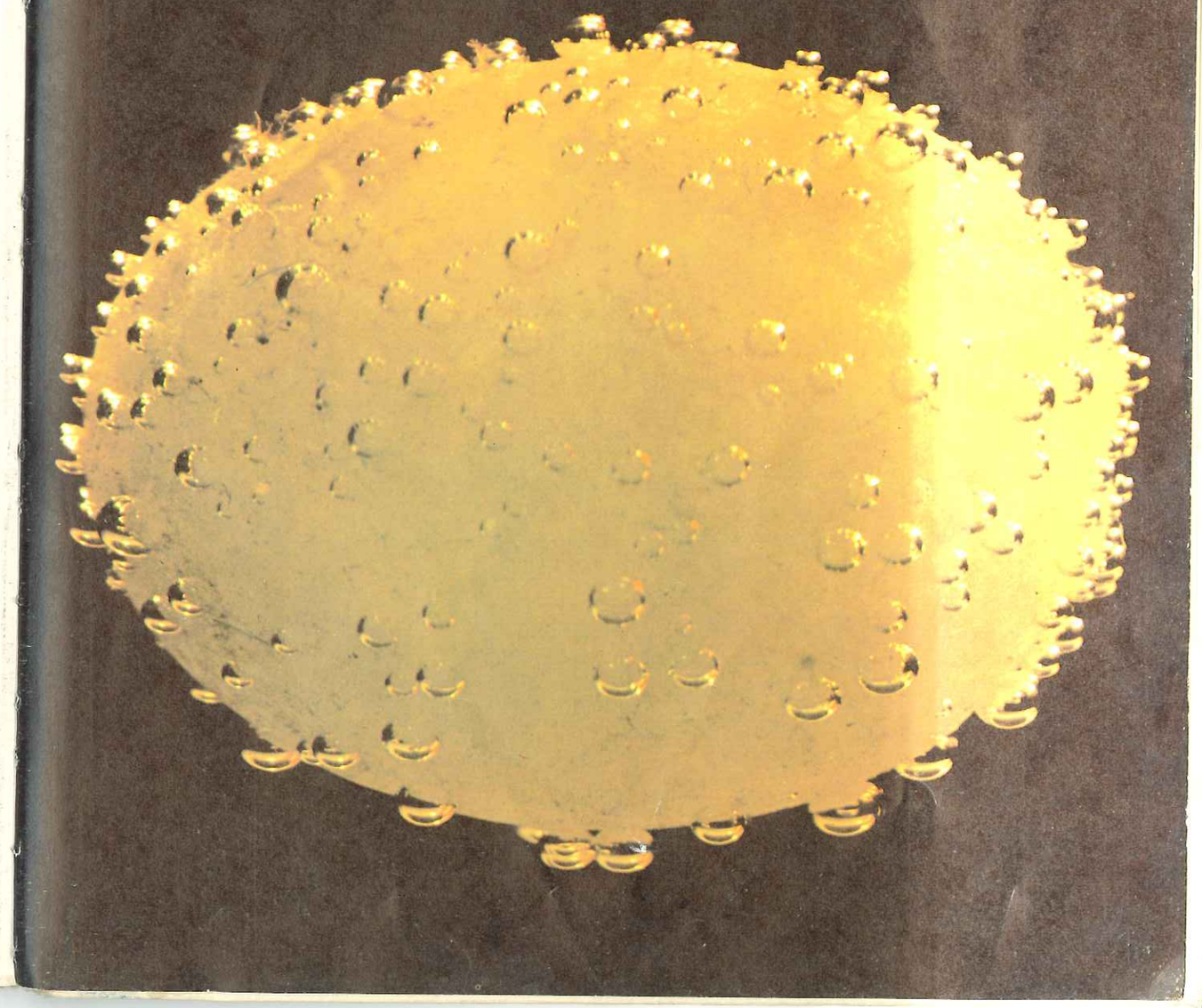


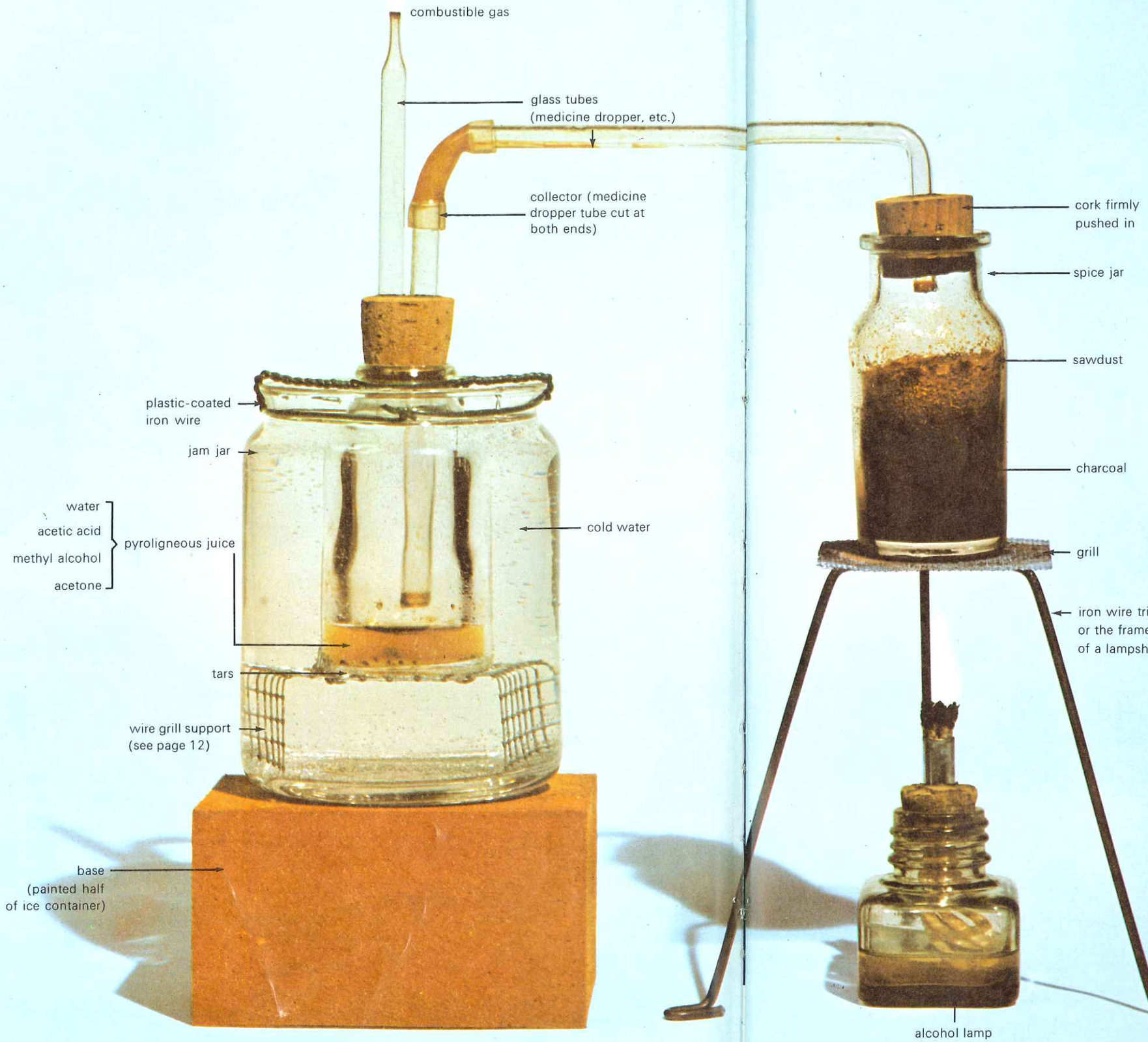


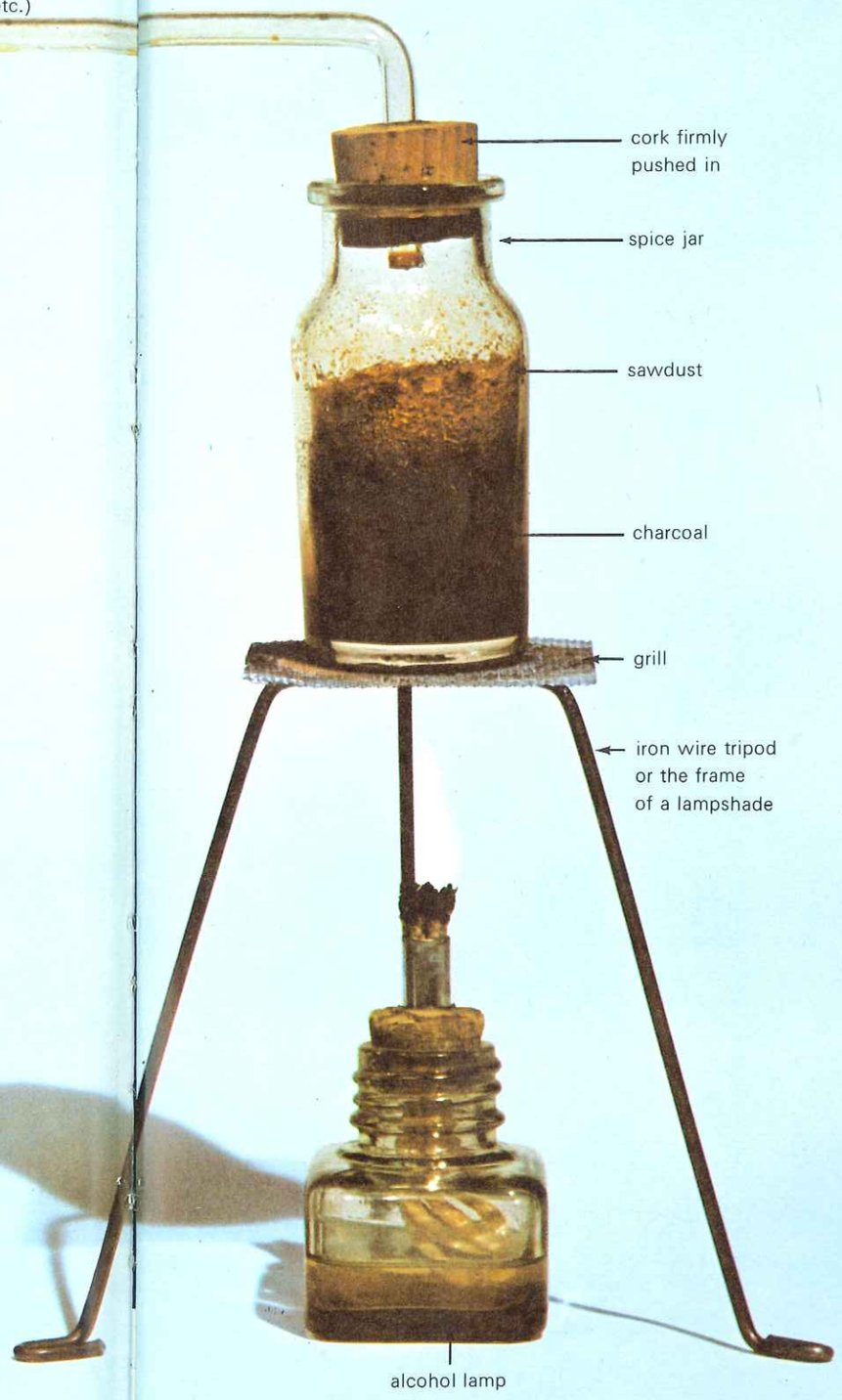


85 The gas works
85 The distilled water works
87 Explosive soap bubbles
88 How to make a bleach
89 How to make an extinguisher
90 Unstable balls

six experiments and unusual applications







The gas works

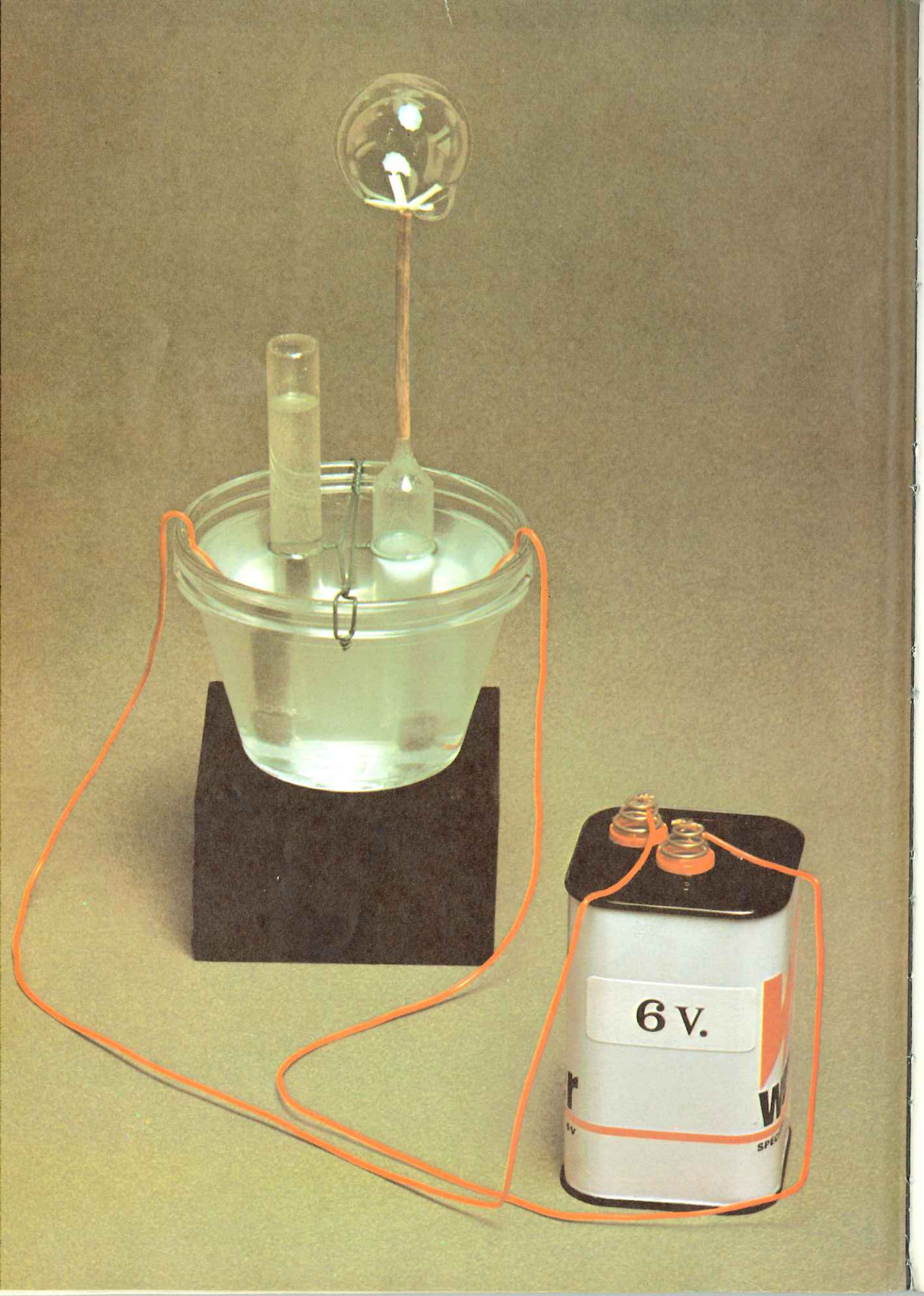
The photograph on the left gives you a full, detailed picture of the supplies and construction methods used for this little installation. It is actually a little chemical factory, which, with sawdust as the raw material, will give you seven different products. This installation will enable you to conduct an experiment called pyrogenation of wood. Heated in a covered jar, wood undergoes a decomposition that ends with the formation of charcoal and volatile products which when cooled give tars and a pyroligneous fluid. It also releases combustible gas that can be ignited.

To cut a small glass tube, place it on a table, and with a small saw, scratch a line around the tube perpendicular to its axis. Now take the tube in both hands (thumbs near the scratch) and break the tube at the scratch. Smooth off the broken edges with emery cloth or better yet, heat them in a gas flame until the glass softens.

Caution: Hold the glass tube in a heavy cloth to protect you from shards of glass if the tube should shatter instead of breaking cleanly. Wear proper eye and face protection since there is a slight possibility of pressure building up that could cause the apparatus to blow apart.

Distilled water works

With the same apparatus except for the sawdust (which is replaced by tap water), you can obtain distilled water in the second jar. If the tip of the tube through which the distilled water passes into the collecting jar is submerged, you must take this tube out of the liquid before you stop heating. If not, the distilled water will back up into the little jar and break it.



Explosive soap bubbles

Supplies: jam jar; glass tube and ampule; insulated electric wire; two pieces of charcoal (or extract two carbon rods from discarded flashlight batteries); stiff insulated wire; epoxy glue or silicone caulk; 6-volt battery; a straw; soapy water (1 part liquid detergent to 5 parts distilled water); distilled water; table salt.

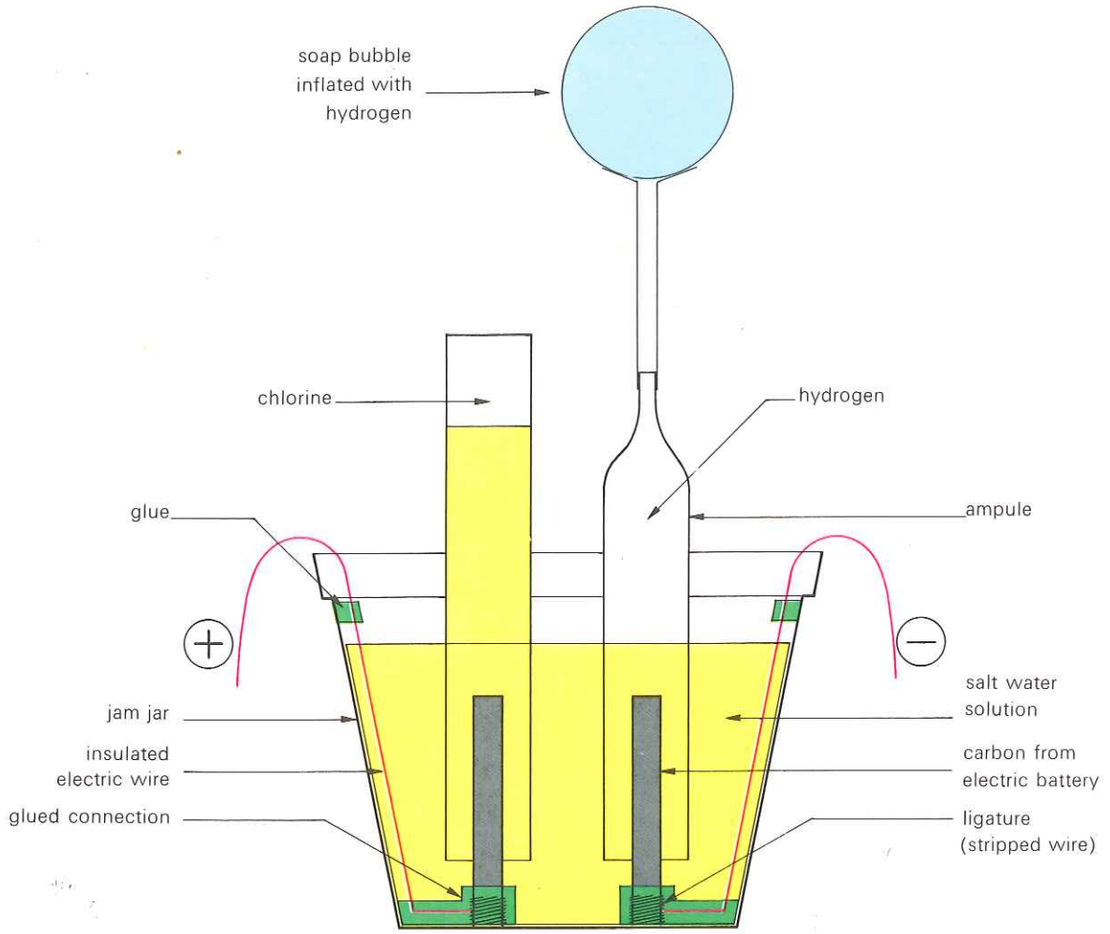
Strip the casing off the tips of two pieces of electric wire and wind them round each carbon rod. Daub these connections with glue or caulk and let dry.

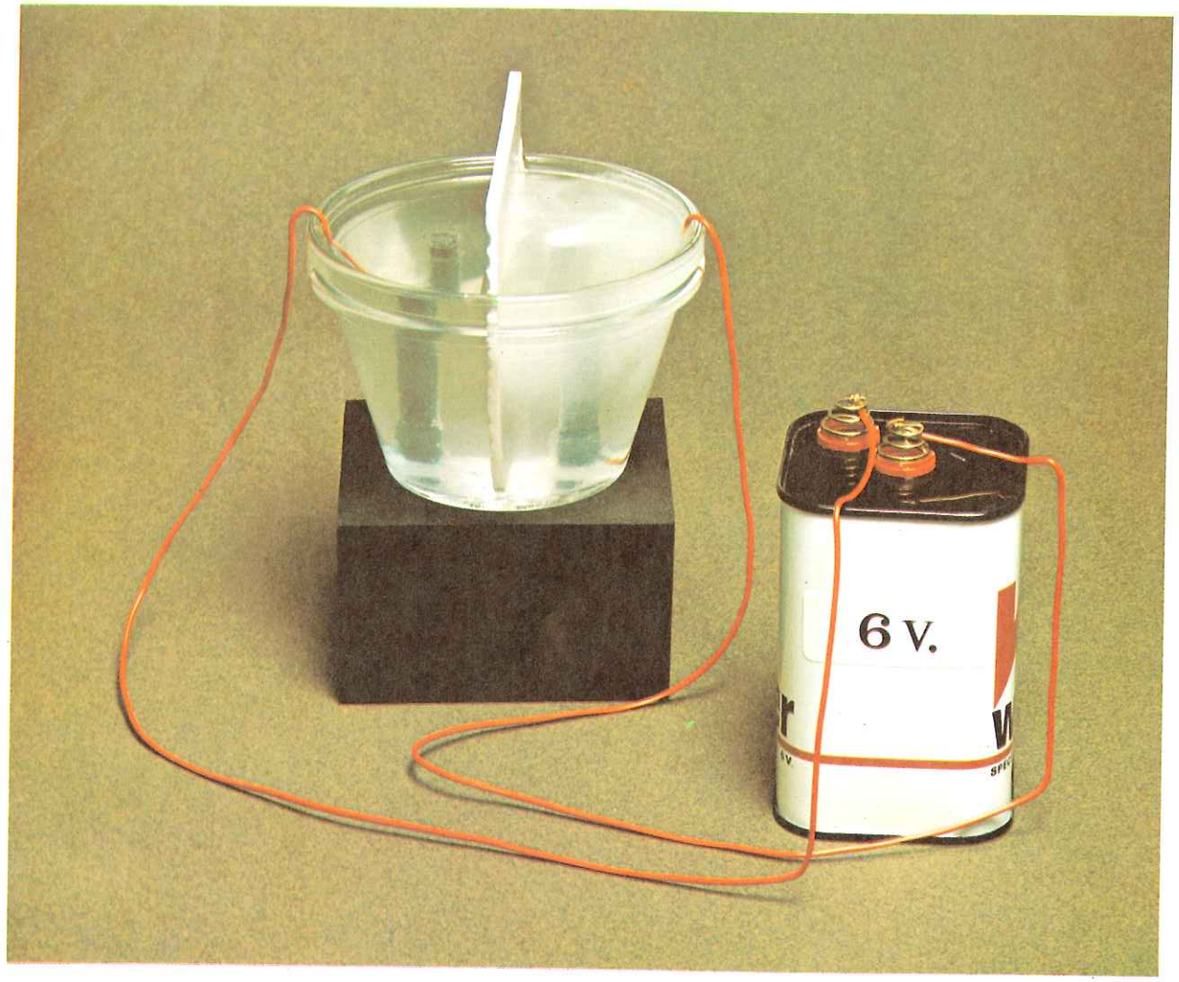
Glue the carbon rods to the bottom of the jar and fix the wires to the rim of the jar with a dab of glue. Make a support for the glass tube and ampule out of wire. The support rests on the rim of the jar and holds the tubes in place over the carbon rods. Dissolve as large a quantity of salt as possible in distilled water. Fill the first tube with this solution, and then the jar. Filling the tube to the brim, place your thumb over the open end as a stopper, turn the tube upside down and place it over the carbon rod.

Split one end of the straw and dip it in the soapy solution and place it on the tapered end of the ampule. Connect the wire from the carbon rod covered by the ampule to the negative terminal of the battery, and the other wire to the positive terminal. The first tube empties slowly, and a bubble forms at the tip of the straw. Tap on the straw with a rod to release the bubble. It will rise quickly to the ceiling, and if you bring a candle flame close to it, it will burst. Naturally, this experiment is not dangerous. However, be careful not to ignite the bubble until it is completely free of the apparatus.

□ The apparatus you have made is a voltameter. The salt-water solution (sodium chloride) gives off chlorine into the first tube and hydrogen into the second when the current passes through. The hydrogen ignites very easily, which is why the soap bubbles explode at the approach of the flame. Be sure to have your teacher explain how to dispose of the chlorine safely.

This experiment requires proper eye and face protection.





How to make a bleach

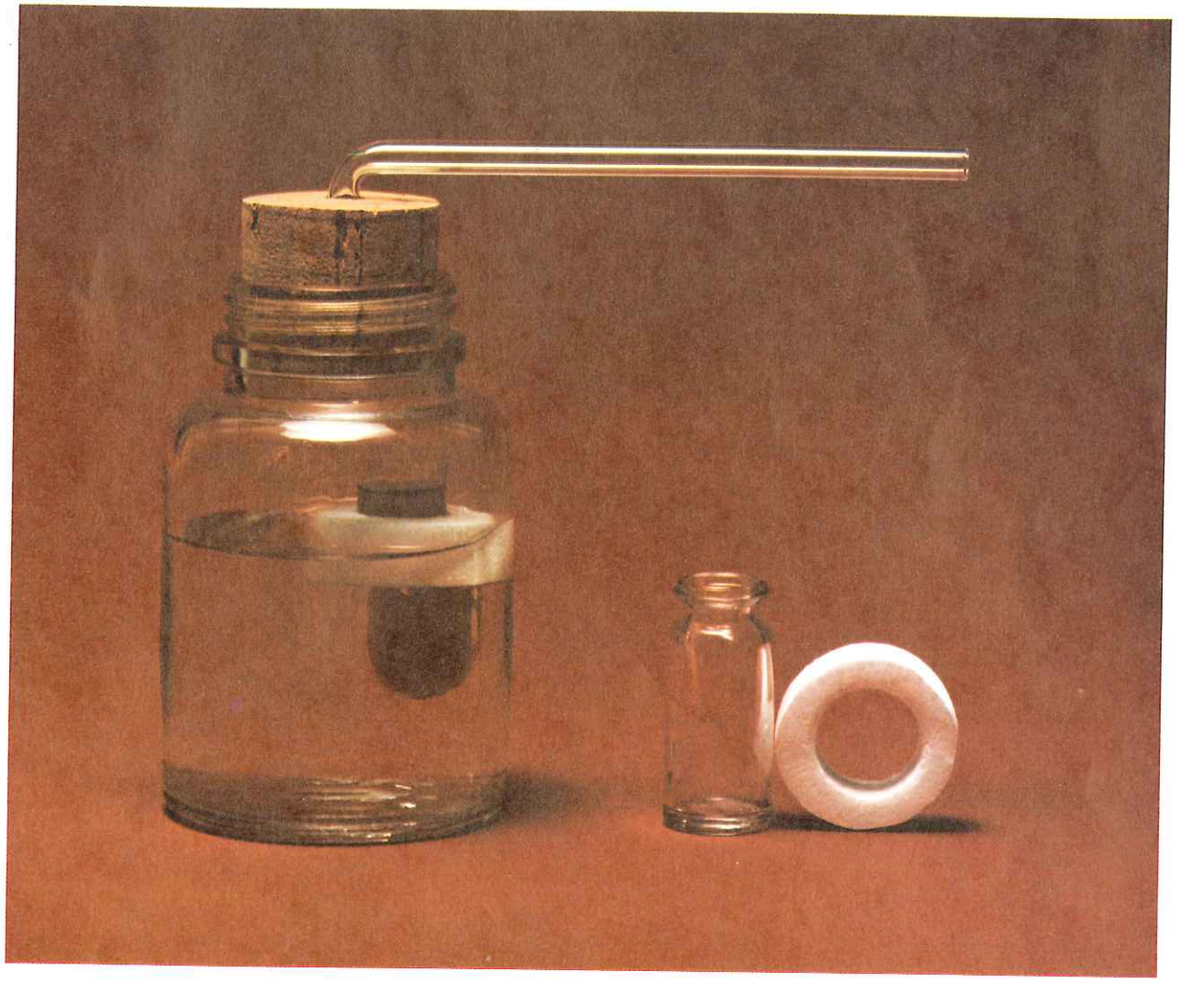
Supplies: jam jar; insulated electric wire; two lumps of charcoal (extract carbon rods from discarded flashlight batteries); epoxy glue or silicone caulk; 6-volt battery, or better, 75 volts; distilled water; table salt; cardboard.

Cut out a divider from cardboard that can be put into the voltameter used in the experiment on page 87. It should divide the jar into two equal compartments, each containing a carbon rod. Dissolve as much salt as possible in distilled water. Pour this solution into the voltameter and insert the divider. Attach the electric wires to the terminals of the battery.

The carbon rod tied into the negative terminal (cathode) releases bubbles of hydrogen. The other rod, attached to the positive terminal (anode), does not seem to be releasing chlorine—yet it is. Chlorine is soluble and will not become visible until it reaches the saturation point. After twenty minutes, however, when bubbles of chlorine appear, cut the current, take out the divider, and stir the liquid with a rod.

The solution thus obtained is sodium hypochlorite, or more simply, Javelle water, which you can surely recognize from its odor. Test its bleaching power by pouring several drops of it into a glass of water colored with a bit of ink or by dipping a violet into it.

Before removing the divider, if you take a sample of the solution in the cathode section using a medicine dropper, you will find soda. To check this, put a little red-cabbage solution (see page 77) in the glass: it will turn blue, for soda is a base.



How to make an extinguisher

Supplies: wide-mouthed bottle; cork; elbow-shaped glass tube; small pharmacist's vial; piece of expanded polystyrene (Styrofoam®); bicarbonate of soda; aluminum sulphate; soapy water (1 part liquid detergent to 5 parts water).

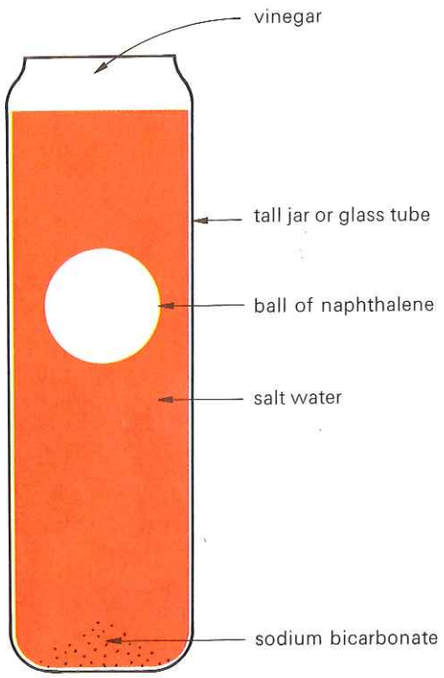
Adjust the cork if necessary to an air-tight fit. File the cork with a rough file, then with a fine one. So that there will be no leaks, its shape should be that of a truncated cone. Pierce the cork so that a glass tube can be put through it. Use a nail heated over a flame or an awl and a rat-tailed file to make the hole larger. Cut a piece of polystyrene to use as a lifesaver for the little bottle (on the right in the photo).

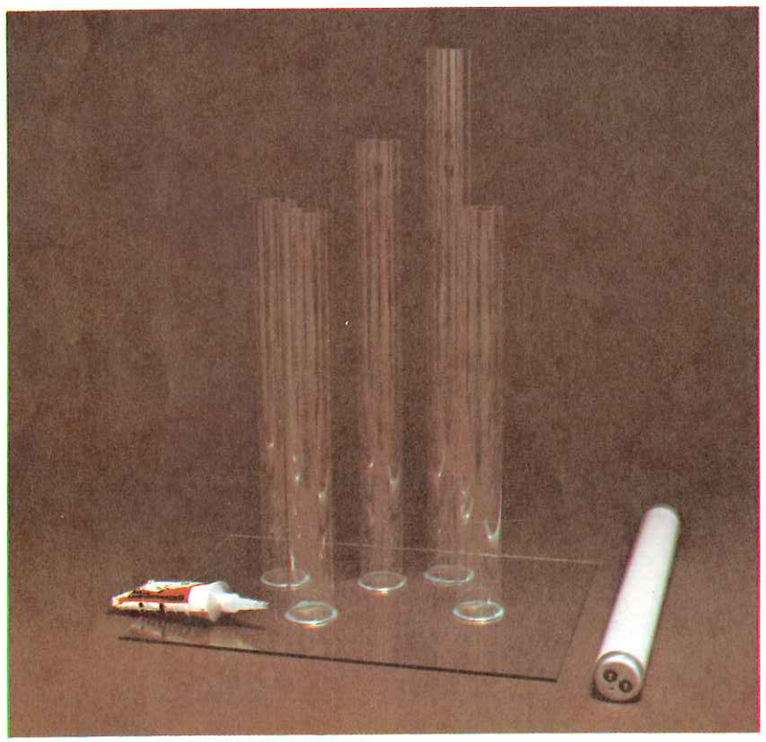
Make a saturated solution of bicarbonate of soda (about 5 grams of soda per 150 cm^3 of water) and fill the large bottle half-way. Then add a little soapy water. Dissolve some aluminum sulphate to the saturation point in a little water and pour this into the little bottle. The latter, provided with a lifesaver, is put in the large bottle. You must place it on the surface of the liquid and make sure it floats vertically.

Close the large bottle air-tight with the cork through which the tube is passed.

To use the extinguisher, shake the bottle so as to cause the two solutions to mix and aim the tube at the flame. A spray of foam will come out and extinguish the flame.

Variation: Replace the aluminum sulphate with tartaric acid. You will get a powerful jet of carbon dioxide when you shake the extinguisher.





Unstable balls

Balls rise and sink endlessly in tubes filled with colored liquids.

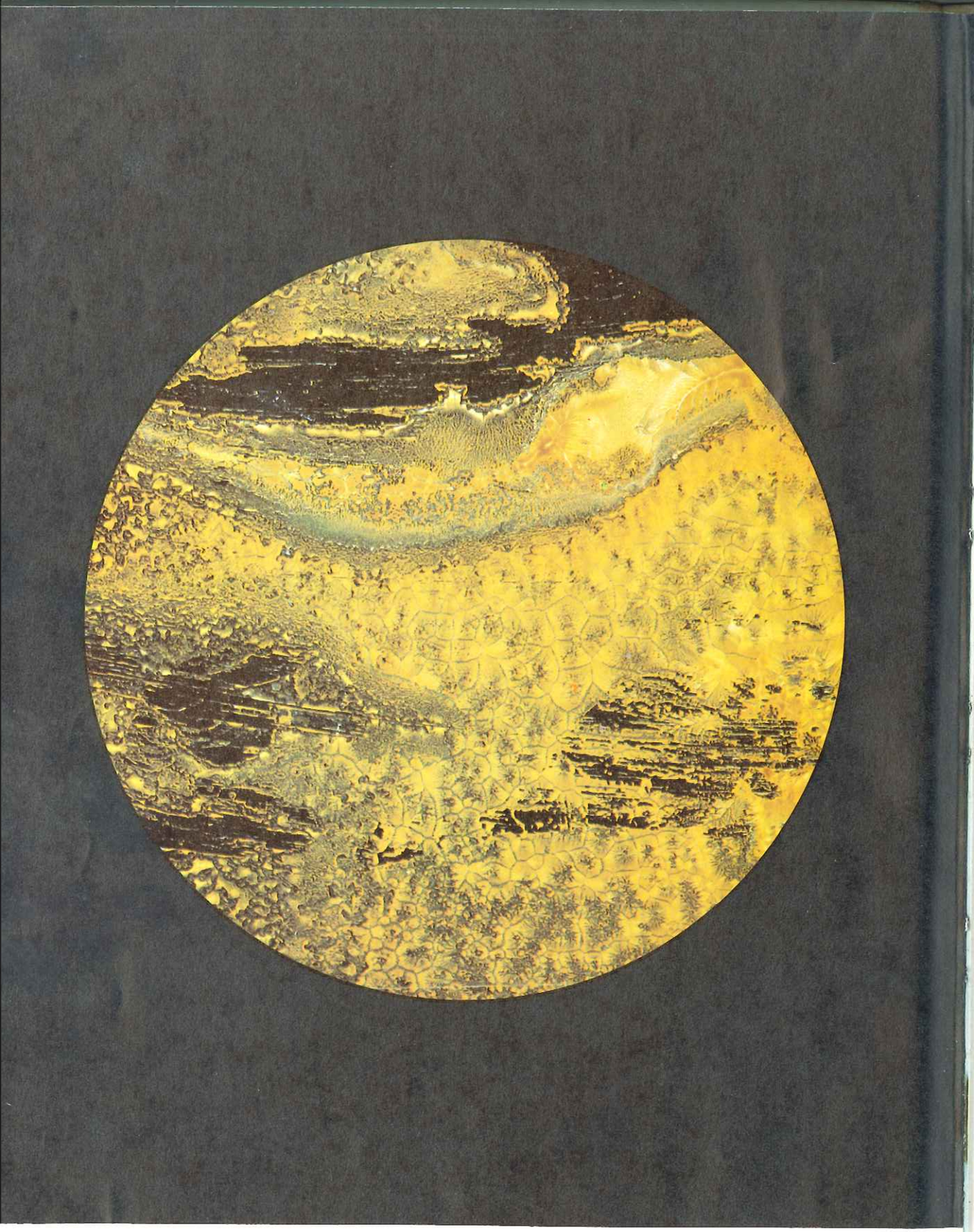
Supplies: naphthalene balls; bicarbonate of soda; white vinegar; table salt; colored ink; tall jar or glass or plastic tube; epoxy adhesive; glass plate.

This experiment can be carried out in an ordinary tall jar, or even better, in glass tubing (as shown in photo) cut and sandpapered at both ends (see page 10). To hold them in place, use epoxy to create a bond between the base of the tubes and the glass plate.

Pour water into the bottle and dissolve enough salt in it to float a naphthalene ball on the surface. Add a bit more water and stir the solution with a rod. Add only enough to cause the ball to sink slowly. Color the liquid with ink.

Then put a little bicarbonate of soda, and then some vinegar and stir with the rod. Now put the naphthalene back into the bottle. It will sink, rise to the surface, sink again and rise over and over for hours if you add a little vinegar and bicarbonate from time to time.
If you do this experiment in the tubes, use inks of different colors.

□ The vinegar and the bicarbonate react and give off carbon dioxide—this is in the little bubbles that you see in the liquid. The salt-water solution, denser than ordinary water, makes the ball lighter and the little bubbles of carbon dioxide cling to it and carry it to the surface. The photo on page 83 shows, greatly enlarged, the ball of naphthalene being dragged by hundreds of tiny gas bubbles. Once at the surface, the bubbles break away, go off into the air and the ball, having become heavier, sinks into the bottle where it again takes on a load of bubbles and rises.



Effect of crystallization on a glass plate (see page 20).

Chemistry, atoms, and the world we live in

Not so long ago, there were no chemists (or, for that matter, no scientists of any sort), for the words "chemistry" and "science" had not even been invented. There were, though, some people who were fascinated by the phenomena of the natural world around them. They observed natural events and thought about what they saw, trying to figure out how the world as a whole operated. These people were called "natural philosophers." While the natural philosophers were often good observers, when it came to how or why an event took place, they generally had to rely on mystical explanations, as they knew little of the basic nature of the universe.

We now know that all matter is composed of atoms. Some substances (known as *elements*) are made up of only one type of atoms, and others (*compounds*) are made up of combinations of the atoms of different elements. We also know that the atoms themselves are composed of yet smaller particles.

In the center of the atom is the *nucleus*. It is made up of heavy particles called *protons* (each of which carries an electric charge of +1) and *neutrons* (which have no electric charge). All atoms of a given type have exactly the same number of protons in their nuclei. Thus all oxygen atoms have 8 protons, all iron atoms have 26 protons, all uranium atoms have 92 protons, etc.

This need not concern us greatly just now, as atomic nuclei stay essentially unchanged during ordinary chemical reactions. The particles that do take part in these reactions are the *electrons.*

The electrons are light particles, each with an electric charge of −1. An atom normally has exactly as many electrons as protons, so that their opposite charges cancel each other. The oxygen atom, for example, has 8 protons (for a charge of +8) and 8 electrons (for a charge of −8) for a net charge of 0—the atom is electrically neutral overall.

While the heavy protons and neutrons are packed into the dense, tiny nucleus, the light electrons are distributed around the nucleus in a much larger space. We can think of the electrons as tiny particles circling around the nucleus as the planets of the solar system orbit the sun. The real situation is, however, far more complicated.

Chemical reactions occur when atoms or *molecules* (combinations of atoms) give up, receive, or share electrons.

Let us take as an example a simple reaction whose product is ordinary table salt. The two constituents of salt are the elements sodium and chlorine. During the reaction, the sodium atom donates one of its electrons to the chlorine atom. This can occur because sodium with one less electron and chlorine with one added electron are said to be in *stable states.*

But now, the sodium atom still has the 11 protons it started the reaction with, but only 10 electrons (it started with 11, of course). There is now one more proton than there are electrons and the atom thus has a net charge of +1. Similarly, the chlorine atom has received one extra electron and thus has a net charge of −1. Atoms that have either lost or gained electrons are called *ions*, and we are now no longer dealing with sodium and chlorine *atoms*, but with sodium and chlorine *ions.*

We would expect these ions to be attracted to each other, as are all objects with opposite electric charges (objects with the same electric charge repel each other). And this is indeed what happens—the ions are bound to each other by their mutual attraction. This is known as an *ionic bond.*

Note that pure sodium is a soft metal that is highly toxic and pure chlorine is a yellowish gas that is also poisonous. But salt is a brittle white crystal that is not only quite tasty, but is absolutely essential for a healthy human being.

Other chemical bonds involve the sharing of electrons rather than simple transfer. The water molecule, for example, is composed of two atoms of hydrogen sharing electrons with one atom of oxygen. The bond occurs because the electrons are in a more stable state when bound than when unbound. This type of bond is called the *covalent bond*, and the shared electrons, instead of orbiting one nucleus, orbit the two nuclei of the bound atoms.

In this case, too, the properties of the compound are very different from those of its constituent elements. Hydrogen and oxygen are both gases, yet water is a liquid. Hydrogen is highly flammable and oxygen supports burning, yet we use water to put out fires.

The idea of chemically combining substances to get new substances is one of the major contributions of chemistry to the world as we know it. In this way, substances that never existed on the earth before chemists made them in the laboratory are finding their way into our everyday lives. Numerous plastics, synthetic fabrics, building materials, foods and drugs are all here today. Tomorrow . . . who knows?

The other important product of chemistry is energy. Every chemical bond is like a tiny battery storing energy. But the energy is lying dormant, and we cannot use it directly. This is referred to as *potential energy.*

When substances react, old bonds are broken and new ones are formed. In some cases, the new bonds contain less energy than the old ones did. What happens to this left-over energy? This is where potential energy is released as useable energy.

Often, the energy released is in the form of heat and light, as in the fireworks experiments in this book. Sometimes it is in the form of electricity, as in the case of an electric battery. So you see that the energy we use to heat and light our homes, power our automobiles, and even keep our own bodies going are all examples of *chemical bond energy.*

It is chemistry that is in large part responsible for the various forms of matter and energy that we see and use every day. The world as we know it would not be possible without chemistry. We have come a long way since the natural philosophers.

Index

alcohol lamp 11
aluminum sulphate 15, 39
  crystals 39
analysis 76–79
apparition, mysterious 46–47
arborescent crystallization 20–21
assaying cup *see* cupel
balls, unstable 90–91
bases 80
benzoic acid 15, 43
  crystals 43
bleach 88
calcium chloride 15
candles, Roman 58–60
carbonization of paper 47
catalyst 70
cautions 15
chameleon, liquid 80–81
chemicals *see* supplies
chlorine 88
Christmas decorations 31–32
chrome alum 15, 29, 32, 36
  crystals 29, 32, 36
chunk of synthetic material 27
cobalt chloride 15, 39, 51
  crystals 39
  effect of humidity on 51
colored flames 68–69
colors, magic 74–82
combustible iron wire 68
combustion *see* fireworks
combustive 70
contagion 32
copper sulphate 15, 20, 23, 27, 35, 39
  crystals 20, 23, 27, 35, 39
coral crystals 34–37
costume jewelry 32
crystals 16–43
  aluminum sulphate 39
  arborescent 20–21
  benzoic acid 43
  chrome alum 29, 32, 36
  cobalt chloride 39
  contagion 32
  copper sulphate 20, 23, 27, 35, 39
  coral 34–37
  giant 22–23
  isomorphs 29
  magnesium sulphate 19, 24, 39
  mineral flowers 27
  nucleus 23
  octahedron 24, 30
  one inside another 28–29
  potassium alum 24, 26, 29, 30, 32, 36, 39
  potassium ferricyanide 20, 32, 35
  projecting 20
  sugar 31
crystallizer 9–10
cupel 9–10
cutting glass 10
dessicant *see* calcium chloride
diamond merchant's chest 26
distilled water works 84–85
enigmas, laboratory 76–79
equipment 8–13
eruption, volcanic 65
explosive soap bubbles 87
extinguisher 89
ferric citrate 15
fire without matches 72–73
fireworks 56–73
fireworks, improvised 72
flames, colored 68–69
flaming sugar 70
flask 9–10
forbidden planet 65–67
forest, underwater 38–41
frost in summer 42–43
funnel 10, 11
gas works 84–85
giant crystals 22–23
glassware 8–10
  making 10
heat-sensitive paper 51
hydrogen 87
improvised fireworks 72
invisible inks 47–51
invisible to visible 44–55
iron, burning 68, 72
isomorphs 29
Javelle water 88
laboratory enigmas 76–79
light-sensitive paper 52–55
liqueur de cailloux 39
liquid chameleon 80–81
liquid or solid? 18–19
magic box 50
magic drawing 48
magic colors 74–82
magic powder 61
magnesium sulphate 15, 19, 24, 39
  crystals 19, 24, 39
measuring glass 10
mineral flowers 27
mortar and pestle 10
mysterious apparition 46–47
nucleus, crystal 23
octahedron 24, 30
one crystal inside another 28–29
paper, carbonization 47
paper, heat-sensitive 51
paper, light-sensitive 52–55
phantom writing 50
photographic reaction 54
planet, forbidden 65–67
potassium alum 15, 24, 26, 29, 30, 32, 36, 39
  crystals 24, 26, 29, 30, 32, 36, 39
potassium ferricyanide 15, 20, 32, 35
  crystals 20, 32, 35
potassium nitrate 15
potassium permanganate 15
powder, magic 61
precious stones 24–25
  see also crystals
prestidigitator 80
projecting crystals 20
pyrotechnics in a thimble 70–71
question and answer game 49
reagents 48, 79
riddle pictures 49
Roman candles 58–60
scales 11–13
  calibration 11
soap bubbles, explosive 87
sodium silicate 15
sphere to octahedron 30
stalactites and stalagmites 19
Stromboli 62–64
sublimation 43
sugar 31, 70
  burning 70
  crystals 31
supplies 14–15
  sources 15
  storage 15
sulphur 15
supports 11, 12
synthetic material, chunk of 27
thimble, pyrotechnics in 70–71
tips 15
ultra-secret ink 49
underwater forest 38–41
unstable balls 90–91
volcanic eruption 65
voltameter 87
warnings 15
weather indicator 51
wire support 11, 12